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AESA BASED IPM PACKAGE

AESA based IPM – Pineapple

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The AESA based IPM - Pineapple, was compiled by the NIPHM working group under the Chairmanship of Dr. Satyagopal Korlapati, IAS, DG, NIPHM, and guidance of Shri. Utpal Kumar Singh, IAS, JS (PP). The package was developed taking into account the advice of experts listed below on various occasions before finalization.

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FOREWORD

Intensive agricultural practices relying heavily on chemical pesticides are a major cause of wide spread ecological imbalances resulting in serious problems of insecticide resistance, pest resurgence and pesticide residues. There is a growing awareness world over on the need for promoting environmentally sustainable agriculture practices.

Integrated Pest Management (IPM) is a globally accepted strategy for promoting sustainable agriculture. During last century, IPM relied substantially on economic threshold level and chemical pesticides driven approaches. However, since the late 1990s there is conscious shift to more ecologically sustainable Agro-Eco System Analysis (AESA) based IPM strategies. The AESA based IPM focuses on the relationship among various components of an agro-ecosystem with special focus on pest-defender dynamics, innate abilities of plant to compensate for the damages caused by the pests and the influence of abiotic factors on pest buildup. In addition, Ecological Engineering for pest management - a new paradigm to enhance the natural enemies of pests in an agro-ecosystem is being considered as an important strategy.The ecological approach stresses the need for relying on bio intensive strategies prior to use of chemical pesticides.

Sincere efforts have been made by resource personnel to incorporate ecologically based principles and field proven technologies for guidance of the extension officers to educate, motivate and guide the farmers to adopt AESA based IPM strategies, which are environmentally sustainable. I hope that the AESA based IPM packages will be relied upon by various stakeholders relating to Central and State government functionaries involved in extension and Scientists of SAUs and ICAR institutions in their endeavour to promote environmentally sustainable agriculture practices.

Date: 6.3.2014

(Avinash K. Srivastava)

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FOREWORD

IPM is a holistic approach of crop protection based on the integration of multiple strategies viz., cultural, physical, mechanical, biological, botanicals and chemical. Over the years IPM underwent several changes, shifting its focus from damage boundary, economic injury to economic threshold. Currently most stake holders rely upon economic threshold levels (ETL) and tend to apply chemical pesticides at the first instance in the event of a pest attack, though Government of India has advocated need based and judicious application of chemicals. This approach is likely to cause adverse effects on agro-ecosystems and increase the cost of agricultural production due to problems of pest resurgence, insecticide resistance and sustainability.

During the late 90s FAO started advocating Agro-Ecosystem Analysis (AESA) based IPM. Experience in different countries have since shown that AESA, which takes into account ecological principles and relies on the balance that is maintained by biotic factors in an ecosystem has also resulted in reduction in cost of production and increase in yields. AESA based IPM also takes into account the need for active participation of farmers and promotes experiential learning and discovery based decision making by farmers. AESA based IPM in conjunction with ecological engineering for pest management promotes bio-intensive strategies as against current chemical intensive approaches, while retaining the option to apply chemical pesticides judiciously as a measure of last resort.

The resource persons of NIPHM and DPPQ&S have made sincere efforts in revising IPM packages for different crops by incorporating agro-ecosystem analysis, ecological engineering, pesticide application techniques and other IPM options with the active cooperation of crop based plant protection scientists working in State Agricultural Universities and ICAR institutions. I hope this IPM package will serve as a ready reference for extension functionaries of Central/ State Governments, NGOs and progressive farmers in adopting sustainable plant protection strategies by minimizing the dependence on chemical pesticides.

(Utpal Kumar Singh)

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PREFACE

Need for environmentally sustainable agricultural practices is recognised worldwide in view of the wide spread ecological imbalances caused by highly intensive agricultural systems. In order to address the adverse impacts of chemical pesticides on agro-ecosystems, Integrated Pest Management has evolved further from ETL based approach to Agro-ecosystem Analysis based Integrated Pest Management (IPM).

In AESA based IPM the whole agro-ecosystem, plant health at different stages, built-in-compensation abilities of the plant, pest and defender population dynamics, soil conditions, climatic factors and farmers' past experience are considered. In AESA, informed decisions are taken by farmers after field observation, AESA chart preparation followed by group discussion and decision making. Insect zoo is created to enable the farmer understand predation of pests by Natural Enemies. AESA based PHM also results in reduction of chemical pesticide usage and conserves the agro-ecosystems.

Ecological Engineering for Pest Management, a new paradigm, is gaining acceptance as a strategy for promoting Biointensive Integrated Pest Management. Ecological Engineering for Pest Management relies on cultural practices to effect habitat manipulation and enhance biological control. The strategies focus on pest management both below ground and above ground. There is a growing need to integrate AESA based IPM and principles of ecological engineering for pest management.

There is a rising public concern about the potential adverse effects of chemical pesticides on the human health, environment and biodiversity. The intensity of these negative externalities, though cannot be eliminated altogether, can be minimized through development, dissemination and promotion of sustainable biointensive approaches.

Directorate of Plant Protection Quarantine and Storage (DPPQS), has developed IPM package of practices during 2001 and 2002. These packages are currently providing guidance to the Extension Officers in transferring IPM strategies to farmers. These IPM package of practices, have been revised incorporating the principles of AESA based IPM in detail and also the concept of Ecological Engineering for Pest Management. It is hoped that the suggested practices, which aim at enhancing biodiversity, biointensive strategies for pest management and promotion of plant health, will enable the farmers to take informed decisions based on experiential learning and it will also result in use of chemical pesticides only as a last resort & in a safe and judicious manner.

(K. SATYAGOPAL)

Contents

AESA BASED IPM PACKAGE FOR PINEAPPLE

Pineapple plant description:

Pineapple (*Ananas comosus* L.; Family: Bromeliaceae) is a tropical plant with edible multiple fruit consisting of coalesced berries, and the most economically significant plant. The pineapple is an herbaceous perennial which grows to 1-1.5 meters tall, although sometimes it can be taller. In appearance, the plant itself has a short, stocky stem with tough, waxy leaves. The plant comes to flowering in 20–24 months and fruiting in the following 6 months. During reproductive growth, it usually produces up to 200 flowers, although some large-fruited cultivars can exceed this. Once it flowers, the individual fruits of the flowers join together to create what are commonly referred to as a pineapple. After the first fruit is produced, side shoots (called 'suckers' by commercial growers) are produced in the leaf axils of the main stem. These may be removed for propagation, or left to produce additional fruits on the original plant. Commercially, suckers that appear around the base are cultivated. A crown cutting of the fruit can also be used as planting material for cultivation. Plant has 30 or more long, narrow, fleshy, trough-shaped leaves with sharp spines along the margins that are 30 to 100 centimeters long, surrounding a thick stem. In the first year of growth, the axis lengthens and thickens, bearing numerous leaves in close spirals. After 12 to 20 months, the stem grows into a spike-like inflorescence up to 15 cm (6 in) long with over 100 spirally arranged, trimerous flowers, each subtended by a bract. Flower colours vary, depending on variety, from lavender, through light purple to red.

The flesh and juice of the pineapple are used in cuisines around the world. In many tropical countries, pineapple is prepared, and sold on roadsides as a snack. It is sold whole, or in halves with a stick inserted. Whole, cored slices with a cherry in the middle are a common garnish on hams in the West. Chunks of pineapple are used in desserts such as fruit salad, as well as in some savory dishes, including pizza toppings and a grilled ring on a hamburger. Crushed pineapple is used in yogurt, jam, sweets, and ice cream. Pineapple does not ripen significantly post-harvest. Pineapples are consumed fresh, cooked, juiced, and preserved, and are found in a wide array of cuisines.

I. PESTS

A. Pests of National Significance

1. Insect and mite pests

1.1 Pineapple mealybug: *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae)

1.2 Pineapple scales: *Diaspis bromeliae* (Kerner) (Hemiptera: Diaspididae)

1.3 Thrips: *Holopothrips ananasi* Costa Lima (Thysanoptera: Phlaeothripidae).

1.4 Pineapple fruit borer: *Strymon megarus* Godart (Lepidoptera: Lycaenidae)

1.5 Pineapple fruit fly: *Melanoloma canopilosum* Hendel, *M. viatrix* Hendel (Diptera: Richardiidae)

1.6 Pineapple red mite: *Dolichotetranychus floridanus* (Banks) (Trombidiformes: Tetranychidae)

2. Nematodes

2.1 Root-knot nematode: *Meloidogyne javanica*

2.2 Root lesion nematode: *Pratylenchus brachyurus*

2.3 Reniform nematode: *Rotylenchulus reniformis*

3. Diseases

3.1 Phytophthora heart (top) rot: *Phytophthora cinnamomi* Rands and *P. nicotianae* Breda de Haan

3.2 Phytophthora root rot: *Phytophthora cinnamomi* Rands

3.3 Base (butt) rot: *Chalara paradoxa* (Dade) C. Moreau

3.4 Fruitlet core rot (green eye): *Fusarium guttiforme* Nirenberg & O'Donnell and *Penicillium funiculosum* Thom

3.5 Fusariosis: *Fusarium guttiforme* Nirenberg & O'Donnell

3.6 Green fruit rot: *Phytophthora cinnamomi* Rands

3.7 Interfruitlet corking: *Penicillium funiculosum* Thom

3.8 Leathery pocket: *Penicillium funiculosum* Thom

3.9 Water blister: *Chalara paradoxa* (Dade) C. Moreau

3.10 White leaf spot: *Chalara paradoxa* (Dade) C. Moreau

3.11 Fruit rot by yeast and candida species: *Saccharomyces* spp. and *Candida* spp.

3.12 Marbling: *Pantoea ananatis* and *Acetobacter* spp.

3.13 Pink disease: *Pantoea citrea*, *Gluconobacter oxydans* or *Acetobacter aceti*

3.14 Mealybug wilt disease: Ampelovirus transmitted by mealy bugs

3.15 Yellow spot: *Capsicum chlorosis* virus (Tospoviruses)

4. Rodents

4.1 Indian Porcupine: *Hystrix indica* (Kerr) (throughout India)

4.2 Lesser bandicoot: *Bandicota bengalensis* (Gray) (throughout India)

4.3 Palm rat/House rat: *Rattus rattus* (Linnaeus) (throughout India)

4.4 Northern Palm squirrel: *Funambulus pennant* (Linnaeus) (Northern parts of India)

4.5 Southern Palm squirrel: *Funambulus palmarum* (Linnaeus) (Southern parts of India)

5. Weeds

Broadleaf

5.1 Pigweed: *Amaranthus viridis* Hook. F. Amaranthaceae

5.2. Common purselane: *Portulaca oleracea* L. Portualacaceae

5.3. False amaranth: *Digera arvensis* Forssk. Amaranthaceae

5.4 Carrot grass: *Parthenium hysterophorus* L. Asteraceae

5.5 Goat weed: *Ageratum conyzoides* L. Asteraceae

5.6 Coat buttons: *Tridax procumbens* L. Asteraceae

Grasses

5.7 Barnyard grass: *Echinochloa crusgalli* (L.) Beauv. Poaceae

5.8 Bermuda grass: *Cynodon dactylon* (L.) Pers. Poaceae

5.9 Cogon grass: *Imperata cylindrica* (L.) Raeusch. Poaceae

Sedges

5.10 Purple nutsedge: *Cyperus rotundus* L. Cyperaceae

5.11 Flat sedge: *Cyperus iria* L. Cyperaceae

B. Pests of Regional Significance

1. Insect pests

1.1 Sugarcane midget: *Elaphira nucicolora* (Guenée) (Lepidoptera: Noctuidae)

1.2 Bud moth: *Opogona sacchari* (Bojer) (Lepidoptera: Tineidae)

1.3 White grubs: *Phyllophaga* spp. (Coleoptera: Scarabaeidae)

1.4 Fig beetle: *Cotinis mutabilis* (Gory and Percheron) (Coleoptera: Scarabaeidae)

1.5 Pineapple weevil: *Diastethus bromeliarum* Champion (Coleoptera: Curculionidae)

II. AGRO-ECOSYSTEM ANALYSIS (AESA) BASED INTEGRATED PEST MANAGEMENT (IPM)

A. AESA:

The IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment ultimately affecting the interests of the farmers. The economic threshold level (ETL) was the basis for several decades but in modern IPM (FAO 2002) emphasis is given to AESA where farmers take decisions based on larger range of field observations. The health of a plant is determined by its environment which includes physical factors (i.e. soil, rain, sunshine hours, wind etc.) and biological factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance which exists between herbivore insects and their natural enemies. Understanding the intricate interactions in an ecosystem can play a critical role in pest management.

Decision making in pest management requires a thorough analysis of the agro-ecosystem. Farmer has to learn how to observe the crop, how to analyze the field situation and how to make proper decisions for their crop management. This process is called the AESA. Participants of AESA will have to make a drawing on a large piece of paper (60 x 80 cm), to include all their observations. The advantage of using a drawing is that it requires the participants/farmers to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

AESA is an approach, which can be gainfully employed by extension functionaries and farmers to analyse field situations with regard to pests, defenders, soil conditions, plant health, the influence of climatic factors and their inter-relationship for growing healthy crop. Such a critical analysis of the field situations will help in taking appropriate decision on management control. The basic componenets of AESA are:

- Plant health at different stages
- Built –in-compensation abilities of the plants
- Pest and defender population dynamics

- Soil conditions
- Climatic factors
- Farmer past experience

Principles of AESA based IPM:

Grow a healthy crop:

- Select a variety resistant/tolerant to major pests
- Select healthy suckers/planting material
- Treat the suckers/planting material with recommended pesticides especially biopesticides
- Follow proper spacing
- Soil health improvement (mulching and green manuring wherever applicable)
- Nutrient management especially organic manures and biofertilizers based on the soil test results. If the dosage of nitrogenous fertilizers is too high the crop becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the crop growth is retarded. So, the farmers should apply an adequate amount for best results. The phosphatic fertilizers should not be applied each and every season as the residual phosphate of the previous season will be available for the current season also.
- Proper irrigation
- Crop rotation

Observe the field regularly (climatic factors, soil and biotic factors):

Farmers should

- Monitor the field situation at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situation and Pest: Defender ratio (P: D ratio)
- Take direct action when needed (e.g. collect egg masses, remove infested plants etc.)

Plant compensation ability:

Compensation is defined as the replacement of plant biomass lost to herbivores and has been associated with increased photosynthetic rates and mobilization of stored resources

from source organs to sinks (e.g., from roots and remaining leaves to new leaves) during active vegetative growth period. Plant tolerance to herbivory can arise from the interaction of a variety of plant traits and external environmental factors. Several studies have documented such compensation through increased growth and photosynthetic rate.

Understand and conserve defenders:

- Know defenders/natural enemies to understand their role through regular observations of the agro-ecosystem
- Avoid the use of chemical pesticides especially with broad-spectrum activity

Insect zoo:

In field various types of insects are present. Some are beneficial and some may be harmful. Generally farmers are not aware about it. Predators (friends of the farmers) which feed on pests are not easy to observe in crop field. Insect zoo concept can be helpful to enhance farmers' skill to identify beneficial and harmful insects. In this method, unfamiliar/unknown predators are collected in plastic containers with brush from the field and brought to a place for study. Each predator is placed inside a plastic bottle together with parts of the plant and some known insect pests. Insects in the bottle are observed for certain time and determined whether the test insect is a pest (feeds on plant) or a predator (feeds on other insects).

Pest: Defender ratio (P: D ratio):
Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of pineapple pests can be divided into 3 categories; 1. parasitoids; 2. predators; and 3. pathogens.

Model agro-ecosystem analysis chart

Date:
Village:
Farmer:

Decision taken based on the analysis of field situations

Soil conditions :
Weather conditions :
Diseases types and severity :
Weeds types and intensity :
Rodent damage (if any) :
No. of insect pests :
No. of natural enemies :
P: D ratio :

The general rule to be adopted for management decisions relying on the P: D ratio is 2: 1. However, some of the parasitoids and predators will be able to control more than 2 pests. Wherever specific P: D ratios are not found, it is safer to adopt the 2: 1, as P: D ratio. Whenever the P: D ratio is found to be favourable, there is no need for adoption of other management strategies. In cases where the P: D ratio is found to be unfavourable, the farmers can be advised to resort to inundative release of parasitoids/predators depending upon the type of pest. In addition to inundative release of parasitoids and predators, the usage of microbial biopesticides and biochemical biopesticides such as insect growth regulators, botanicals etc. can be relied upon before resorting to synthetic chemical pesticides.

Decision making:

Farmers become experts in crop management:

Farmers have to make timely decisions about the management of their crops. AESA farmers have learned to make these decisions based on observations and analysis viz. abiotic and biotic factors of the crop ecosystem. The past experience of the farmers should also be considered for decision making. However, as field conditions continue to change and new technologies become available, farmers need to continue improving their skills and knowledge.

- Farmers are capable of improving farming control by experimentation
- Farmers can share their knowledge with other farmers

AESA methodology:

- Go to the field in groups (about 5 farmers per group). Walk across the orchard and choose 20 plants/ acre randomly. Observe keenly each of these plants and record your observations:

    - Plant: Observe the plant height, number of branches, crop stage, deficiency symptoms etc.
    - Pests: Observe and count pests at different places on the plant.
    - Defenders (natural enemies): Observe and count parasitoids and predators.
    - Diseases: Observe leaves and stems and identify any visible disease symptoms and severity.
    - Rats: Count number of plants affected by rats.
    - Weeds: Observe weeds in the field and their intensity.
    - Water: Observe the water situation of the field.
    - Weather: Observe the weather condition.

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will then analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant representing the field situation. The weather condition, water level, disease symptoms, etc. will be shown in the drawing. Pest insects will be drawn on one side. Defenders (beneficial insects) will be drawn on another side. Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose in the following weeks.

Data recording:

Farmers should record data in a notebook and drawing on a chart

- Keeping records of what has happened help us making an analysis and draw conclusions

Data to be recorded:

- **Plant growth (weekly):** Height of plant; number of leaves
- **Crop situation (e.g. for AESA):** Plant health; pests, diseases, weeds; natural enemies; soil condition; irrigation; weather conditions
- **Input costs:** Seeds; fertilizer; pesticides; labour
- **Harvest:** Yield (Kg/acre); price of produce (Rs./Kg)

Some questions that can be used during the discussion:

- Summarize the present situation of the field.
- What crop management aspect is most important at this moment?
- Is there a big change in crop situation compared to last visit? What kind of change?
- Is there any serious pest or disease outbreak?
- What is the situation of the beneficial insects?
- Is there a balance in the field between pests and defenders?
- Were you able to identify all pests and diseases?

- Do you think the crop is healthy?
- What management practices are needed at this moment?
- When will it be done? Who will do it? Make sure that responsibilities for all activities are being discussed.
- Are you expecting any problems to emerge during the coming week such as congenial weather conditions for pest buildup?
- What are the problems? How can we avoid it? How can we be prepared?
- Summarize the actions to be taken.

Advantages of AESA over ETL:

One of the problems of the ETL is that it is based on parameters that are changing all the time, and that are often not known. The damage or losses caused by a certain density of insects cannot be predicted at all. In ETL the due recognition of the role of natural enemies in decreasing pest population is ignored. Farmers cannot base their decisions on just a simple count of pests. They will have to consider many other aspects of the crop (crop ecology, growth stage, natural enemies, weather condition, etc.) and their own economic and social situation before they can make the right crop management decisions. In ETL based IPM, natural enemies, plant compensation ability and abiotic factors are not considered. In AESA based IPM emphasis is given to natural enemies, plant compensation ability, abiotic factors and P: D ratio.

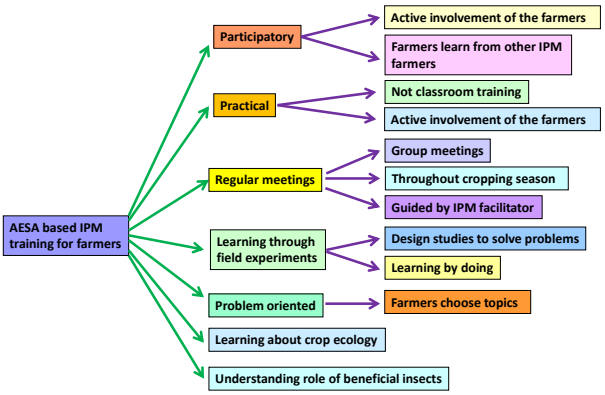
AESA and farmer field school (FFS):

AESA is a season-long training activity that takes place in the farmer field. It is season-long so that it covers all the different developmental stages of the crop and their related management control. The process is always learner-centered, participatory and relying on an experiential learning approach and therefore it has become an integral part of FFS.

Farmers can learn from AESA:

- Identification of pests and their nature of damage
- Identification of natural enemies
- Management of pests
- Water and nutrient management
- Influence of weather factors on pest buildup
- Role of natural enemies in pest management

FFS to teach AESA based IPM skills:



B. Field scouting:

AESA requires skill. So only the trained farmers can undertake their exercise. However, other farmers also can do field scouting in their own fields at regular intervals to monitor the major pest situation.

Surveillance on pest occurrence at the main field should commence soon after crop establishment after transplanting and at weekly intervals thereafter. In each of the fields, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

For insect pests:

Scales, mealy bug and mites: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

Thrips: Count and record the number of nymphs and adults of thrips present on five terminal leaves per plant (tapping method also can be used to count thrips).

***Strymon*, *Elaphira* and *Melanoloma*:** Total number of fruits, damaged fruits due to *Strymon*, *Elaphira* and *Melanoloma* and number of larvae on individual plants should be counted and recorded.

***Phyllophaga*, *Diastethus* and *Cotinis*:** Number of larvae of *Phyllophaga* (root borer), *Diastethus* (stem borer) and *Cotinis* [flower (adult) and root (grub) damage] on individual plants should be counted using a suitable procedure.

For diseases:
Whenever scouting, be aware that symptoms of plant disease problems may be caused by any biotic factors such as fungal, bacterial, viral pathogens or abiotic factors such as weather, fertilizers, nutrient deficiencies, pesticides and abiotic soil problems. In many cases, the cause of the symptom is not obvious. Close examination, and laboratory culture and analysis are required for proper diagnosis of the causal agent of disease. Generally fungal diseases cause the obvious symptoms with irregular growth, pattern & colour (except viruses), however abiotic

problems cause regular, uniform symptoms. Pathogen presence (signs) on the symptoms can also be observed like fungal growth, bacterial ooze etc. Specific and characteristic symptoms of the important plant diseases are given in description of diseases section.

Root sampling: Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth or ooze). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discolouration & signs). Count the total number of roots damaged/infested/infected due to rot should be counted and incidence should be recorded.

Leaf sampling: Examine all leaves and/or sheaths of each plant for lesions. Leaf diseases cause most damage during the seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Determine the percent area of leaf infection by counting the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

Stem, flower and fruit sampling: Carefully examine the stem, flower, and fruit of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower, and fruit should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems, flowers and fruits infected due to disease and percent disease incidence should be recorded.

C. Blue pan water/sticky traps

Set up blue pan water/sticky traps 15 cm above the canopy for monitoring for thrips @ 4-5 traps/acre. Locally available empty tins can be painted blue coated with grease/ Vaseline/ castor oil on outer surface may also be used.

D. Light traps

Set up light traps @ 1 trap/acre at the height of middle of crop canopy for monitoring and mass trapping insects. Light traps with exit option for natural enemies of smaller size should be installed and operate around the dusk time (6 pm to 10 pm).

E. Nematode extraction

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

III. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

Ecological engineering for pest management has recently emerged as a paradigm for considering pest management approaches that rely on the use of cultural techniques to effect habitat manipulation and to enhance biological control. The cultural practices are informed by ecological knowledge rather than on high technology approaches such as synthetic pesticides and genetically engineered crops (Gurr *et al*., 2004a,b).

Natural enemies may require

1. Food in the form of pollen and nectar for adult natural enemies.
2. Shelter such as overwintering sites, moderate microclimate etc.
3. Alternate hosts when primary hosts are not present.

Ecological engineering for pest management – Above ground:

- Raise the flowering plants/ compatible cash crops along the field border by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the field
- Not to uproot weed plants those are growing naturally such as *Tridax procumbens, Ageratum* sp, *Alternanthera* sp etc. which act as nectar source for natural enemies
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological engineering for pest management – Below ground:

- Crop rotations with leguminous plants which enhance nitrogen content.
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.
- Apply balanced dose of nutrients using biofertilizers.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR)
- Apply *Trichoderma harzianum*/*viride* and *Pseudomonas fluorescens* as sucker/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

Due to enhancement of biodiversity by the flowering plants, parasitoids and predators (natural enemies) number also will increase due to availability of nectar, pollen, fruits, insects, etc. The major predators are a wide variety of spiders, ladybird beetles, long horned grasshoppers, *Chrysoperla,* earwigs, etc.

Ecological Engineering Plants

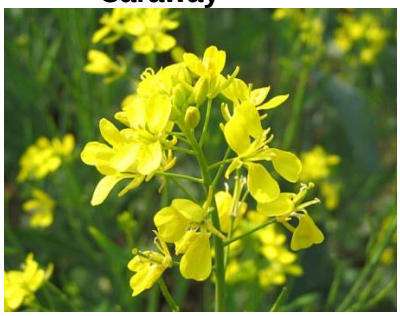
Attractant plants

Anise

Caraway

Dill

Parsley



Mustard

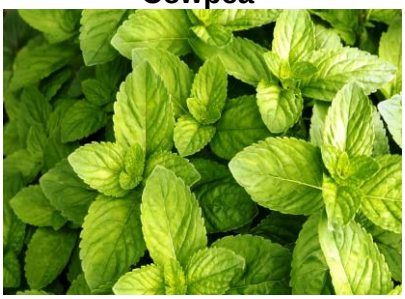
Sunflower

Buckwheat

Cowpea

Carrot

French bean



Spearmint

Ryegrass

Citrus

Banana

Cassava

Papaya

Cotton

***Desmodium* spp.**

***Sesbania* spp.**

***Crotalaria* spp.**

***Chrysanthemum* spp.**

Marigold

***Gaillardia* spp.**

Cluster bean

Border crops

Maize

Sorghum

Pearl millet

Ryegrass

Intercrops

Tomato

Garlic

Repellant plant

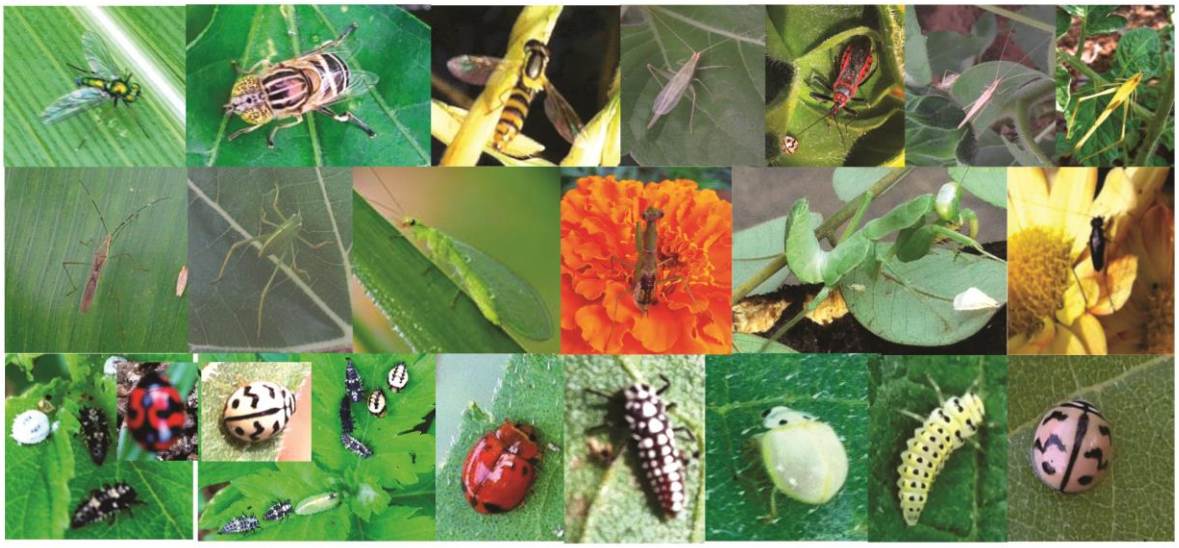
Marigold

The flowering plants suggested under Ecological Engineering for pest management strategy are known as attractant plants to the natural enemies of the selected pests. The information is based on published research literature. However, the actual selection of flowering plants could be based on availability, agro-climatic conditions and soil types

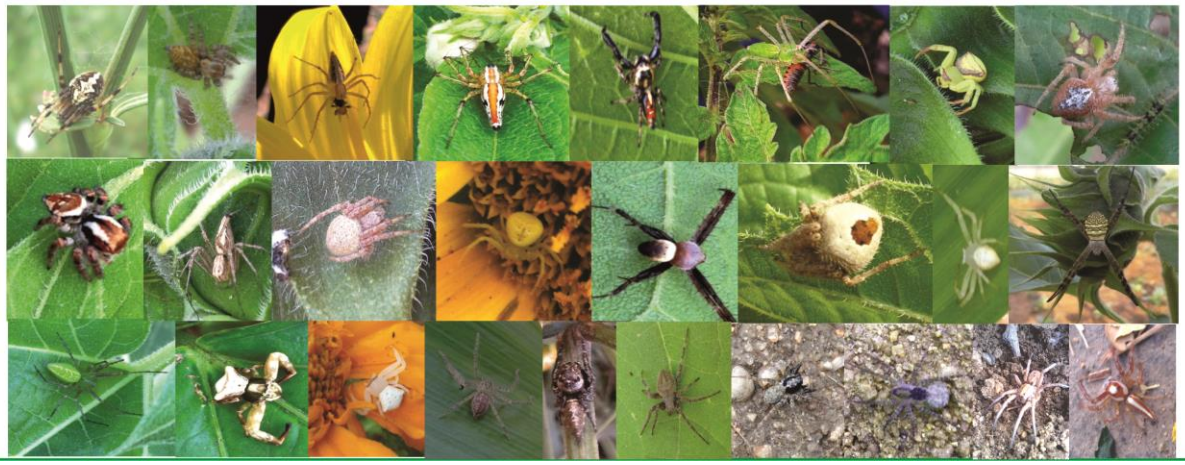
Biodiversity of natural enemies observed in Ecological Engineering field at NIPHM

Biodiversity of natural enemies: Parasitoids

Biodiversity of natural enemies: Predators



Biodiversity of natural enemies: Spiders



IV. CROP STAGE-WISE IPM

Management	Activity
Pre-planting*	
	<u>Common cultural practices:</u> • Destroy the alternate host plants • Sow the ecological engineering plants • Sow sorghum/maize/pearl millet in 4 rows all around the main crop as a guard/barrier crop • Plough the field before planting to destroy existing weeds in the field. • Plough deep after harvest to bury the pupae.
Nutrient	• The field should be prepared very thoroughly by digging and ploughing up to a depth of 40-50 cm to obtain fine tilth. • Nutrient should be supplied on the basis of soil test report and recommendation. • Apply 8-10 tonnes of FYM or compost and 50 Kg phosphorus/acre at the time of last ploughing. • After leveling, the land is laid out into trenches alternating with mounds for planting the suckers. For double row system of planting, two shallow furrows about 10-15 cm depth are to be opened.
Weed	• Remove existing weeds/rhizomes from the field at the time of planting.
Planting*	
	<u>Common cultural practices:</u> • Collect and destroy plant parts infested with insect pest and diseases • Use weed free, healthy suckers for planting. • Remove and destroy crop residues. • Avoid planting during wet weather condition • Take up planting in shade free area
Nutrient	• Planting is done double rows system with a plant to plant spacing of 45 cm and row to spacing of 60 cm. The double rows are spaced at 1.5 to 2.0m. • If FYM is not applied at the time of field preparation, apply FYM or compost @ 2 Kg per sucker at the time of planting. • Add mycorrhiza inoculants @ 5 g per plant pits/ trenches at the time of planting.
Weed	• Remove weeds form the pit/trenches, if any before planting.
Rodent	**<u>Mechanical control</u>:** • Use traps to reduce rodent population by using locally available attractive baits
Nematode	**<u>Cultural control</u>:** • Maintain weed free and host free fallow period of at least for 6 month for significant decline in nematode population • Thorough land preparation will reduce nematode population (it will allow the soil to dry out and accelerates the break down of plant material harbouring nematodes)
Pest	• Follow common cultural practices
***** Apply *Trichoderma viride/harzianum* and *Pseudomonas fluorescens* as	

seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).	
Vegetative stage	
	<u>Common cultural practices:</u> • Collect and destroy crop debris • Collect and destroy disease infected and insect damaged plant parts • Provide irrigation at critical stages of the crop • Enhance parasitic activity by avoiding chemical spray, when 1-2 larval parasitoids are observed • Remove weed plants **<u>Common mechanical practices:</u>** • Handpick the older larvae during early stages • Collect and destroy plant parts infested with insect pest and diseases • Handpick the gregarious caterpillars and the cocoons which are found on stem and destroy them in kerosene mixed water. • Use yellow sticky traps @ 4-5 trap/acre • Use light trap @ 1/acre and operate between 6 pm and 10 pm • Install pheromone traps @ 4-5/acre for monitoring adult moths activity (replace the lures with fresh lures after every 2-3 weeks) • Erecting of bird perches @ 20/acre for encouraging predatory birds such as King crow, common mynah etc. • Set up bonfire during evening hours at 7-8 pm **<u>Common biological practices:</u>** • Conserve natural enemies through ecological engineering • Augmentative release of natural enemies
Nutrient	• After plants have been established, apply 16 g nitrogen, 2 g phosphorus and 3 g potash/plant, two to three times. • Apart from application of 8-10 tonnes of FYM, apply 140 kg nitrogen and 16 kg potash/ acre in three split doses at 2, 5 and 8 months after planting.
Weed	• After planting, whenever weeds appear interculture should be done without digging of the soil deep. • Weeding is done at least three to four times in a year. • Mulching with dry grasses, straw, sawdust, coirdust, rice husk, plastic mulch, etc. will also help to suppress weed growth, conserve moisture and maintain the humus status of soil. • Grow inter crop/ cover crop in between the rows, to suppress the weed growth in spaces between the rows.
Mealybug	**<u>Cultural control:</u>** • Avoid using 5-6 years old suckers for planting • Mealybug spread can be minimized by destroying ant colonies. • The mealybug infested fields must be prepared by removing all the plant residues and incinerating them. • Remove weeds present in the field as they support a hike in mealybug population by giving them alternate food resources. • Remove alternate hosts such as Hibiscus, custard apple, guava in and around crop field.

	• Use sterilized equipment when taking up planting and intercultural operations in an uninfested field. **<u>Biological control:</u>** • Application of *Beauveria bassiana*/*Verticillium lecanii* @ 5 ml/g (2x 108 cfu/ml or g)/ l of water is effective during high humid months • Release eggs or first instar larvae of *Chrysoperla* spp. @ 2-3 grubs/plant. • Follow biological practices
Scale	• Follow common cultural, mechanical and biological practices
Thrips	**<u>Cultural control:</u>** • Mulching reduces thrips infestation considerably • Intercrop with plants that have a natural repellence to thrips such as citronella, garlic and pyrethrum. • Establish windbreaks as they reduce thrips population **<u>Biological control:</u>** • A spray made of garlic and pepper will control thrips. • Two bulbs of garlic and some hot chilli peppers should be blended in some water. After blending the solid parts should be filtered. Add water up to 5 litres and this solution can be applied. • Mix 2 kg of fresh plant material of *Andrographis paniculata* with 250 ml of water and grind it well. Add 21 litres of cow urine and 10 g of crushed dried chilli fruits. Add 10 litres of water and leave the solution for some time. Filter the solution and it is ready for spraying. • Wash fresh roots of *Derris eliptica* and cut them into short pieces of 5 cm length. Add small amount of water and pound the roots until they are finely shredded. Filter the solution. Dilute with soap and water at a ratio of 1 part soap: 4 parts root solution: 225 parts water. Apply immediately. • Follow common biological practices
***Phytophthora* heart (top) rot**	**<u>Cultural control:</u>** • Avoid excessively deep planting • Prevent soil entering the heart during planting • Maintain proper drainage for minimizing the risk of *Phytophthora* infection. • Planting on raised beds of at least 20 cm height • Constructing drains to intercept run-off before it reaches plantation • Constructing drains within field so that water can be removed quickly without causing erosion • Installing underground drains. • Liming materials which increase pH should be used cautiously as *P. cinnamomi* become active at pH above 4 in the soil • In high nutrient soils, *P. nicotianae*, becomes active so apply fertilizers optimally.
***Phytophthora* root rot**	**<u>Cultural control</u>:** • Same as in *Phytopthora* heart rot.
Base (butt) rot	**<u>Cultural control</u>:** • Do not leave a portion of fruit attached to the crown when picking

	• Improve soil drainage
Reproductive (fruit) stage	
	Common cultural practices: •Remove weeds around the plants. •Collect and destroy the plant debris and diseased plants. •Maintain proper drainage **Common biological practices:** •Conserve natural enemies through ecological engineering •Augmentative release of natural enemies
Nutrients	• Apply recommended micronutrients, if deficiency symptoms are observed.
Weeds	• Use straw or plastic/ straw mulch to avoid weed growth and to maintain soil moisture for longer period.
Pineapple fruit borer	• Follow common biological practices
Pineapple fruit fly	**Cultural control:** • Plucking off of infested fruits and fermented fruits and destroying them or expose them to sun to kill developing larvae. • Bagging or netting of fruits.
White grubs/root grubs	**Cultural control:** • The cultural control of late-spring and early-fall ploughing or disking provide control. • Crop rotation is the most effective method. **Biological control** • Follow common biological practices
Pineapple weevil	**Cultural control:** • After two plant cycles replant with new suckers • Use fresh disease free suckers for planting • Collect and burn the crop waste in and around the field • Follow crop rotation with non-host crops • Restrict the movement of infected plant parts to other areas **Biological control** • Follow common biological practices
Pineapple red mite	**Cultural control:** • The best management action is to plant only mite-free seed-plant material. • Population densities of mites can be reduced by lower or minimal fertilizer applications.
Termites	**Cultural control:** • Select low termite risk areas for planting • Use termite resistant varieties suitable for that region • Reduce mechanical damage to the plants • Removal of termite nests • Increasing biodiversity by interplanting reduces termite damage • Clear the area of the material that could attract termites before planting • Completely remove and burn the tree stumps
Pest	• Cow urine: Dilute one litre of cow urine in ten litres of water and

management options for pineapple pests	wet the whole plant at the rate of 80-120 l/acre at regular intervals. • Cow dung: 12.5 kg of fresh cow dung and 12.5 litres of cow urine are collected in an earthen pot and mixed thoroughly with 12.5 litres of water. The pot is covered and the mixture is allowed to ferment for a week. Occasionally it is stirred with a stick. After a week of fermentation, the mixture is filtered and 100 g of lime is added. The concentration is diluted with water in a 1: 10 ratio and sprayed on the crop at 80-100 l/acre. • Neem oil spray: Neem oil spray: 2% neem oil is mixed with any detergent powder at 40– 50 g/100 l and used as a spray solution. • Herbal mixture spray: About 500 g of tobacco leaves, 1 kg of neem kernel, 500 g lime powder, 500 g datura leaves and 500 g pods and seeds of oleander (*Nerium oleander*) are powdered and mixed together, then soaked in 15 litres of water for 15 days. On alternate days, the mixture needs to be stirred with a stick. After 15 days, one litre of filtrate is mixed in 15 litres of water and sprayed on the crop. It is enough for 2.5 ha and is a multi-pest repellent (Joy, Anjana and Sowmya 2013).
Fruitlet core rot (green eye), fusariosis, green fruit rot, interfruitlet corking, leathery pocket	• Follow common cultural practices
Water blister	**<u>Cultural control</u>:** • Collect and destroy the plant debris and diseased plants. • Handle fruit carefully to avoid bruising and scuffing (rapid fungal invasion occurs even minute, weeping fractures) • Reject sun burnt and damaged fruit because these have minor skin cracks that are readily infected • Remove pineapple refuse and rejected fruit from in and around packing shed • Maintain proper drainage
Fruit rot by yeast and candida species	**<u>Cultural control</u>:** • Collect and destroy the plant debris and diseased plants. • Protect the young developing fruit with paper bags in frost prone areas • Discard the fruit showing even minor interfruitlet cracking • Any fruit showing fractures between fruitlets should be picked at the earliest stages of fruit maturity to minimize losses
Mealybug wilt disease	**<u>Cultural control</u>:** • Use planting materials from wilt free areas or from fields with a low level of wilt disease • If <3% plants show wilt symptoms then remove the infected plants by hand and destroy them • If >10% plants show wilt symptoms do not use the field as a source of planting material • Eradicate badly affected areas immediately after harvest • Keep main fields and field boundaries free of weeds and trash which may act reservoirs for ants and mealybugs
Yellow spot	**<u>Cultural control</u>:**

	• Avoid destroying old weedy patches near young crown planting or fields with developing fruit (to prevent spread of thrips to fruits)

V. INSECTICIDE RESISTANCE AND ITS MANAGEMENT

Insecticide resistance: Resistance to insecticides may be defined as 'a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species' (IRAC). Cross-resistance occurs when resistance to one insecticide confers resistance to another insecticide, even where the insect has not been exposed to the latter product.

Causes of resistance development: The causes and rate at which insecticide resistance develops depend on several factors, including the initial frequency of resistance alleles present in the population, how rapidly the insects reproduce, the insects' level of resistance, the migration and host range of the insects, the insecticide's persistence and specificity, and the rate, timing and number of applications of insecticide made. For instance, insect pests that survive in large populations and breed quickly are at greater advantage of evolving insecticide, especially when insecticides are misused or over-used.

General strategy for insecticide resistance management: The best strategy to avoid insecticide resistance is prevention and including insecticide resistance management tactics as part of a larger integrated pest management (IPM) approach.

1) Monitor pests: Monitor insect population development in fields to determine if and when control measures are warranted. Monitor and consider natural enemies when making control decisions. After treatment, continue monitoring to assess pest populations and their control.

2) Focus on AESA. Insecticides should be used only as a last resort when all other non-chemical management options are exhausted and P: D ratio is above 2: 1. Apply biopesticides/chemical insecticides judiciously after observing unfavourable P: D ratio and when the pests are in most vulnerable life stage. Use application rates and intervals as per label claim.

3) Ecological engineering for pest management: Flowering plants that attract natural enemies as well as plants that repel pests can be grown as border/intercrop.

4) Take an integrated approach to managing pests. Use as many different control measures as possible viz., cultural, mechanical, physical, biological etc. Select insecticides with care and consider the impact on future pest populations and the environment. Avoid broad-spectrum insecticides when a narrow-spectrum or more specific insecticide will work. More preference should be given to green labeled insecticides.

5) Mix and apply carefully. While applying insecticides care should be taken for proper application of insecticides in terms of dose, volume, timing, coverage, application techniques as per label claim.

6) Alternate different insecticide classes. Avoid the repeated use of the same insecticide, insecticides in the same chemical class, or insecticides in different classes with same mode of action and rotate/alternate insecticide classes and modes of action.

7) Preserve susceptible genes. Preserve susceptible individuals within the target population by providing unsprayed areas within treated fields, adjacent "refuge" fields, or habitat attractions within a treated field that facilitate immigration. These susceptible individuals may outcompete and interbreed with resistant individuals, diluting the resistant genes and therefore the impact of resistance.

VI. NUTRITIONAL DEFICIENCIES

Nitrogen: Stunted growth. Pale green to light yellow color (chlorosis) appearing first on older leaves, usually starting at the tips. Depending on the severity of deficiency, the chlorosis could result in the death and / or dropping of the older leaves.
Correction measure: Foliar spray of urea @1-2 % at fortnightly intervals.

Phosphorus: Symptoms appear on older leaves. The leaves are small and narrow with purplish or bronze discolouration. Leaves develop necrotic areas and fall off.
Correction measure: Soil application of phosphotic fertilizer or Foliar spray of DAP@2%.

Potassium: Potassium symptoms appear first in older leaves having orange, yellow to pale green colour. Upper surface show reddish purple discoloration. Young leaves remain dark green. Leaves curl down and lose luster and turgidity.
Correction measure: Foliar spray of K2SO4 1% at fortnightly intervals.

Calcium: Young emerging leaves show chlorosis become pale green and curl down. Leaves later turn to greenish pink or red colour. The terminal shoot poorly developed.
Correction measure: Application of CaSO4 @ 2kg / tree/year.

Boron: Fruit necrosis which begins with the browning of inner most part of the mesocarpic tissues at the time of endocarp hardening. This is extended towards the epicarp resulting into brownish black areas on the fruit surfaces depending of the severity of the disorder.

Correction measure: Foliar spray of borax@0.5%

Copper: Plants show overall droopy appearance with shortened intervals between petiole. Size of leaves reduced.
Correction measure: Foliar spray of 1-2% CuSO4.

Iron: Symptoms are first seen in the youngest leaves. The leaves eventually turn completely chlorotic.
Correction measure: Foliar spray of FeSO4@0.5-1.0%.

Zinc: Stunted growth narrowing of leaves with pale green or yellow color. Inter-veinal chlorosis starting from tip of leaflets and spreading to the remaining area leaving only the midrib green.
Correction measure: Foliar spray of ZnSO4 @ 0.5%.

VII. COMMON WEEDS

1. Pigweed: *Amaranthus viridis* Hook. F. (Amaranthaceae)

2. Common purselane: *Portulaca oleracea* L. (Portualacaceae)

3. False amaranth: *Digera arvensis* Forssk. (Amaranthaceae)

4. *C*arrot grass: *Parthenium hysterophorus* L. (Asteraceae)

5. Goat weed: *Ageratum conyzoides* L. (Asteraceae)

6. Barnyard grass: *Echinochloa crusgalli* (L.) Beauv. (Poaceae)

7. Bermuda grass: *Cynodon dactylon* (L.) Pers. (Poaceae)

8. Purple nutsedge: *Cyperus rotundus* L. (Cyperaceae)

9. Flat sedge: *Cyperus iria* L. (Cyperaceae)

10. Coat buttons: *Tridax procumbens* L. (Fabaceae)

11. Cogon grass: *Imperata cylindrica* (L.) Raeusch. (Poaceae)

VIII. DESCRIPTION OF INSECT PESTS

1) Mealybug:

Pineapple mealybug are ovoviviparous i.e., the eggs hatch within the female and give birth to larvae. They appear as cottony, small, oval, soft-bodied sucking insects. They are in variety of forms, of which pink coloured ones are commonly referred to as pineapple mealy bug. They mainly inhabit on seed material. These bugs have mobility only at younger stage

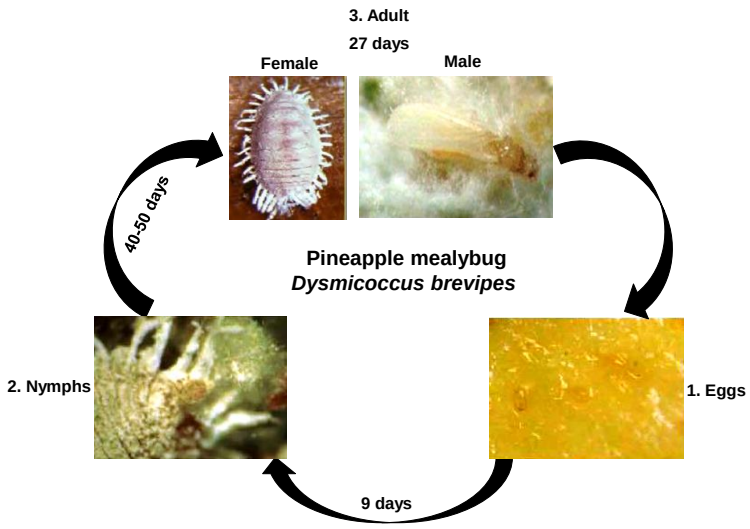
Biology:

Egg: These are minute, varying from 0.3 to 0.4 mm in length. Its development takes between three and nine days.

Nymph: The nymphal stage contributes to complete dispersal of the bugs since their body is extensively covered with hairs. Hence they are called crawlers. The nymphal period extends up to 40-50 days. The first, second and third instars of larval stages last for 10 to 26 days, 6 to 22 days and 7 to 24 days respectively. Larvae only feed as a first instar and in the early part of the second instar.

Adult: Adult females have soft, convex, pinkish body. Also their body is surrounded by 17 pairs of wax filaments. Lateral wax filaments are usually less than one fourth as long as the breadth of the body, and those towards the back of the insect are one-half as long as the body. The prelarviposition period for adult females lasts for around 27 days. The larviposition (giving birth to larvae) period lasts for an average of 25 days. They give birth to about 234 progenies but may produce up to 1000 crawlers. She may then live for another 5 days before dying. Duration of adult female varies from 31-80 days with an average of 56 days. There may be as many as 15 generations. Adult males are having a distinguishable number of eight antennal segments.
Total life span 95 days.

Life cycle:



1,2,4, http://cep.unep.org/repcar/proyectos-demostrativos/costa-rica-1/publicaciones-proagroin/Guia%20manejo%20integrado%20en%20pina%20ENG.pdf
3. http://prsvkm.tripod.com/Docs/PestsofPineappleandthierManagement.pdf

Damage symptoms:

- Mealy bugs become lethal when their population gets increased since the bugs suck the sap from leaves causing the plant to wilt.

- They are dispersed by ants. The sugary secretions of the mealy bug attract ants and they carry them making it vast spread. Also the excretion of honey inhibits the plants ability to manufacture food, form chlorosis of underlying plant tissues and cause rotting and leaking of fruits.
- When fruits are infested they become entirely covered with white, waxy coating making it unfit for marketing.
- Leaves appear pale green to yellow streaks; tips become brown.
- The predominant symptom is wilting of leaves commencing from the leaf tips.
- Reddish-yellow colour manifests in the wilting areas.
- Mealy bug causes quick wilt (result in yellow or red leaves) under heavy infestation or slow wilt (no definite colour change) in mild attack due to root damage.

1. **2.** **3.** **4.**

1. http://www.infonet-biovision.org/default/ct/144/crops
2. http://www.runetwork.org/html/en/articles/7036/preview_to_print.html
3,4, http://www.pestnet.org/SummariesofMessages/Crops/Fruitsnuts/Pineapple/Mealybugwilt,Antigua.aspx

Natural enemies of mealybug:

Parasitoids: 1. *Anagyrus ananatis*, 2.*Anagyrus kamali*

Predators: 1. Ants, 2. *Cryptolaemus montrouzieri,* 3. *Rodolia fumida,* 4. *Scymnus coccivora,* 5. *Dicyphus hesperus,* 6. Dragonfly, 7. Damselfly, 8. Spider, 9. Robber fly, 10. Praying mantis, 11. Fire ants, 12. Lacewings, 13. *Cheilomenes sexmaculata*

2) Pineapple scale:

Scale insects have three distinct life stages (egg, immature, adult) and may complete several generations in a single year.

Biology:

Egg: Adult females produce eggs beneath the scale covering or in a cottony material, and in many cases spend the cold winter months in this stage.

Larva: Tiny six-legged crawlers emerge from the eggs, move to newer growth on the plant, insert their mouthparts and begin to feed. A scale-like covering produced from waxy filaments and feces then forms over each individual scale.

Adult: Scale species are identified by the colour and shape of the covering. The covering protects scales from predation by other insects and from insecticides. The male scale is often a slightly different shape than the female and passes through a tiny, winged stage. The casual observer seldom sees winged stages. Females are wingless and usually remain in one place after inserting their mouthparts into plant tissues.

http://prsvkm.tripod.com/Docs/PestsofPineappleandthierManagement.pdf

Damage symptoms:

- A symptom of an attack is rust coloured spots.
- The insect is found beneath secretion, which serves as a shield.
- In the case of this insect the scale or protective armor is made up partly of a waxy secretion of the insect and partly of molted skins. The insect itself in the adult stage is quite well buried beneath the epidermis of the plant and hence there is necessity of combating the pest in its early stages.
- During periods of large populations, some scales become so abundant that an infested plant tissue is totally encrusted with insects.

Natural enemies of pineapple scales:

Parasitoids: *Aphytis chrysomphali*, *Encarsia citrinus, Encarsia perniciosi*

Predators: *Rhyzobius lophanthae, Chilocoris infernalis, Pharoscymnus flexibilis, Telsimia nitida*, Predatory thrips

3) Thrips:

Biology:

Egg: Females have a saw-like structure that helps to make an incision in plant tissue for egg laying. Usually eggs are laid into incisions in the epidermis of the leaves and stems of young plants. Eggs are elliptical, white, approximately 0.02 cm in length, placed singly, just under the epidermis of succulent leaf, flower, stem or bulb tissue. They are whitish at deposition and change to an orange tint as development continues. It will hatch within 4 to 10 days. Hatching young will immediately begin to suck sap and fluids containing nutrition.

Larva: Larvae as well as the adult insects pierce the leaves and swallow the sap. Pupation takes place in the ground. The emerging adult is about 1 mm long and has a yellow-brown colour with dark cross stripes on the body. There are two larval stages and besides the adults they are the only damaging stages. Larval development is completed in about 9 days.

Pupa: There are two non-feeding stages called the prepupa and pupa. They do not feed and occur primarily in the soil. Combined prepupal and pupal development is completed in 4-7 days.

Adults: Adults are 0.02 cm long. Their body colour ranges from pale yellow to dark brown; wings are unbanded and dirty grey. Males are wingless and exceedingly rare. Females live for about two to three weeks and each can lay about 80 eggs. Mating for reproduction is not

necessary. Females produce only female offspring without mating. Females can produce up to 80 eggs, that is why large populations can be generated within a short period. The entire life cycle is estimated as three weeks producing 5-10 generations in a year.

http://prsvkm.tripod.com/Docs/PestsofPineappleandthierManagement.pdf

Damage symptoms:

- Thrips feed on the plant sap by damaging the leaves. The typical appearance of the damage is a silvery-flecked leaf surface which in severe cases turns brown. These leaves cannot sufficiently photosynthesise.
- Small black spots on the leaves, the excrements of the insects, are a sign of thrips infestation.
- Most thrips rest tightly against leaf veins or in crevices. They are primarily active during the daylight hours.
- Thrips are responsible for the transmission of many fungal and viral diseases in plants.
- When infestations are heavy, people and animals will be troubled with stinging thrips.
- These can also have positive effects on plants. A few species prey on destructive mites and scale insects, resulting in the formation of leaf mould.

Natural enemies of thrips:

Predators: Predatory mite, predatory thrips, *Orius insidiosus,* Coccinellids etc.,

4) Pineapple fruit borer:

The pineapple fruit borer is considered as one of the principal pests of pineapple. The larvae bore into the fruit causing holes and uneven fruit development. Damage from this pest varies greatly but can reach more than 90% and drier climates seem to favour borer attack. In most cases fruit borer attacks occur during flowering and formation of the fruit, though this borer can attack slips and rarely act as a leaf miner.

Biology:

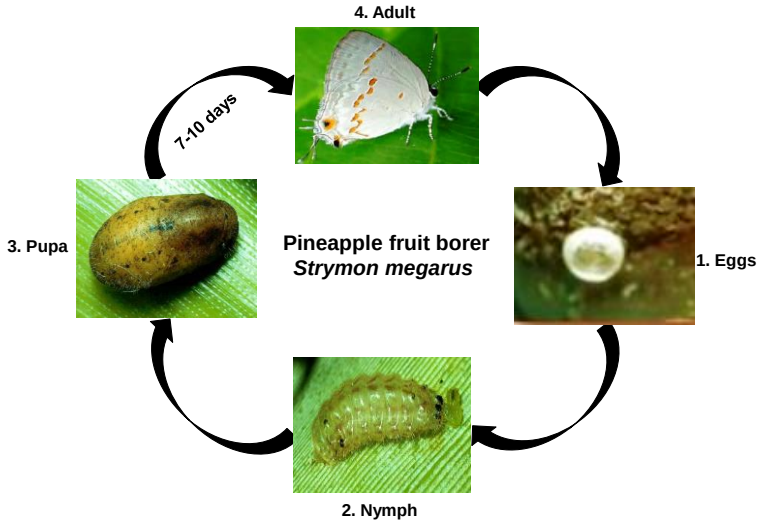
Egg: Eggs are white, circular and slightly flat and approximately 0.8 mm in diameter.

Larva: Larvae complete their development within the fruit. Burrowing and feeding activities produce visible damage in the form of frass production and a sticky, gummy exudate.

Adult: The reddish coloured caterpillar penetrates the inflorescence and remains in the tissue for 15 days, tunnelling and destroying the tissue. After this phase it moves to the base of the peduncle changing into a pupa 12 mm long and 5 mm wide with a brown colour and a few dark spots and emerges 7 to 10 days later as a butterfly. As the caterpillar destroys the

tissues of the inflorescence a resin coloured liquid gum is exuded from between the fruitlets, which in contact with the air becomes reddish coloured and as it solidifies, turns dark brown. The adult moth has a greyish upper wing surface and a cream colour underneath with a wingspan of 28 mm to 35 mm. The adult can be found during the day or night, flying in a rapid and haphazard fashion. Eggs are laid on flowers from emergence to the end of flowering.

Life cycle:



1.http://cep.unep.org/repcar/proyectos-demostrativos/costa-rica-1/publicaciones-proagroin/Guia%20manejo%20integrado%20en%20pina%20ENG.pdf
2,3 http://butterfliesofamerica.com/strymon_megarus_immatures.htm
4. http://prsvkm.tripod.com/Docs/PestsofPineappleandthierManagement.pdf

Damage symptoms:

- The fruit borer larvae open galleries in the pulp, producing an oozing called "gummosis" on the outer side of the fruit.
- Insect damage leads to product rejection at the packing plant.

1. http://cep.unep.org/repcar/proyectos-demostrativos/costa-rica-1/publicaciones-proagroin/Guia%20manejo%20integrado%20en%20pina%20ENG.pdf

Natural enemies of pineapple fruit borer:

Predators: Mirid bug (*Dicyphus hesperus*), reduviid bug, big eyed bugs (*Geocoris* sp) rove beetle, dragonfly, damselfly, spider, robber fly, praying mantis, red ants, lacewings etc.,

5) Bud moth:

Biology:

Egg: The eggs are hatched in 12 days.

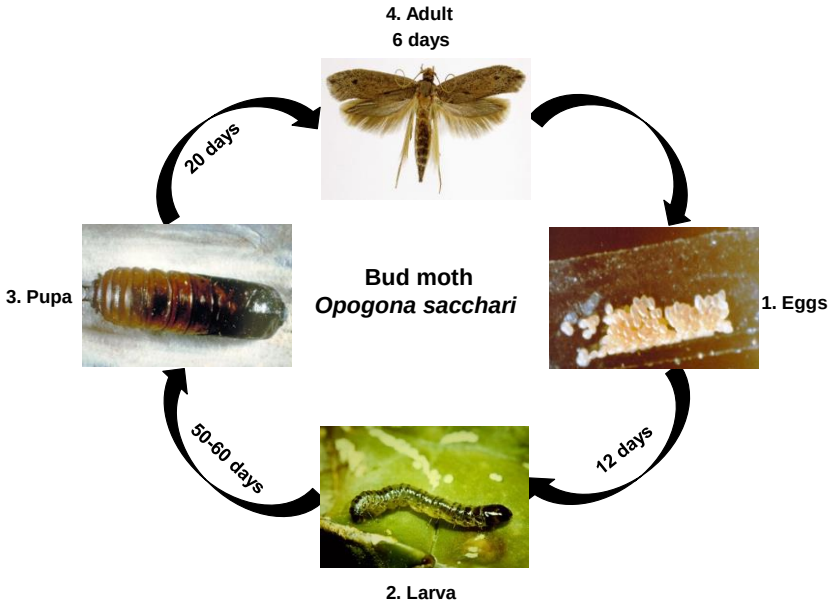
Larva: The eggs develop to larvae within 50-60 days. They are mobile and avoid light. The organism is infectious at this stage. It has seven instars of growth. The larvae appear as dirty-white and somewhat transparent and have a bright reddish-brown head with one lateral ocellus (small eye) at each side and clearly visible brownish thoracic and abdominal plates. They measured 21-26 mm in length having a diameter of 3 mm. The presence of older larvae can be detected by characteristic masses of bore-meal and frass (excreta) at the openings of bore-holes.

Pupa: This stage lasts only for 20 days. The pupae are brown coloured and are of 10 mm and formed in a cocoon of 15 mm size. As the maturation progresses the pupae works itself to move to the next adult stage.

Adult: Its life is only for 6 days. The females lay eggs in crevices of the plant tissue. It lays approximately 200 eggs. The adult is nocturnal and having a length of 11 mm with a wing span of 18-25 mm. They are bright yellowish brown. The forewings may show longitudinal darker brown banding and in the male a dark-brown spot towards the apex. The hind wings are paler and brighter. When they are at rest their antennae are pointed forwards.

The life span totally depends on temperature and it gets shortened at warmer conditions causing only eight generations per year

Life cycle:

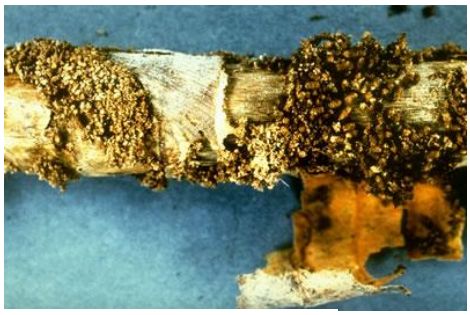


1,2,3 . http://www.eppo.int/QUARANTINE/insects/Opogona_sacchari/OPOGSC_images.htm
4. http://www2.nrm.se/en/svenska_fjarilar/o/opogona_sacchari.html

Damage symptoms:

- Bud moth's larvae normally feed on decaying plant parts and further infesting surrounding healthy tissue. Also it attacks leaves and thus destroying the xylem tissues causing the leaves to wilt.
- The total growth of the plant retarded and further the whole plant perished.

- A secondary infection of plant parasites and fungal pathogens make the effect more critical.
- When they attack on mature fruit they bore into the peel of the fruit causing exudation of secondary metabolites like gum.



1. Feeding damage on cortex layer **2. Frass deposits**

Natural enemies of bud moth:

Predators: Coccinellids, mirid bug (*Dicyphus Hesperus*), reduviid bug, dragonfly, damselfly, spider, robber fly, praying mantis, red ants, lacewing, big eyed bugs (*Geocoris* sp), rove beetle

6) Pineapple fruit fly:

Biology:

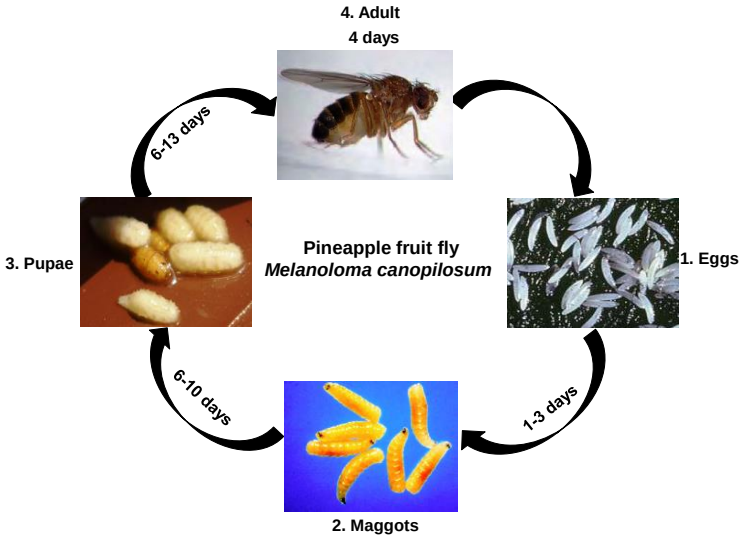
Egg: The female flies lay eggs within the fruit. The eggs are white and are tapered at the ends with a length of about 1.2 mm. They appear in colonies.

Larvae: They are plant feeders. Sometimes they behave as saprophages invading decayed plant material. They also infest on fruits. They form cavities within the fruit which grow and coalesce and are called “spot with galleries”. All further development of the larvae takes place within the fruit. This further causes fermentation of the fruit. The larvae develop are yellowish white, vermiform and devoid of legs. Their total length is approximately 9.5 mm which is made up of 11 segments. Of which three pairs are at the thoracic region and there is a head region and the eighth at the abdominal region. The head region has small retractable cone shape with internal mandibular hooks. The first segment of the thorax has a pair of anterior spiracles with short extensions 12 to 14 digits. At the caudal region pair of posterior spiracles presents. Each of them has three openings surrounded by esclerotizada. At the outward area from them form a series of projections in the form of hairs called inter spiracular processes. The larvae mainly inhabit at the shell and fleshy part of the fruit.

Pupa: Larvae continued to inhabit in fruits until the pupa state. Pupa stage lasts 15 to 20 days under laboratory conditions. The pupae are reddish brown, cylindrical capsule also with 11 segments. They project to a length of 5 mm with a diameter of 1.8 mm. The spiracles present are distinctive in nature and have well defined cephalic area.

Adult: They have conspicuously pictured wings with metallic blue or greenish colour on the body and legs. Also they are ovipositors and lay eggs in fruits. Adult grows up to 5- 6.5 mm long having wingspan of about 1 cm. They are black coloured with abundant micropubescecias. They have wide and short scuttellum. They presents with thorny hind femora of equal thickness. Their wings are clear devoid of any protrusions. It has a dark spot along its entire length. This extended to the wing margin and divide at the subcosta. The radial vein appears dark and cubitoanal cell is somewhat round.

Life cycle:



1,2,3,4. http://prsvkm.tripod.com/Docs/PestsofPineappleandthierManagement.pdf

Damage symptoms:

- Pineapple fruit fly as the name defines it mainly infests fruits.
- The fruit damage starts when the female fruit fly punctures the fruit with its long and sharp ovipositor.
- The fruit skin is breached, and bacteria enter and the fruit starts to decay.
- The larvae that hatch from the eggs feed on the decaying fruit tissue, and on the yeasts and bacteria that multiply in it. Also the larvae groove into the pineapple.

7) White grub:

Biology:

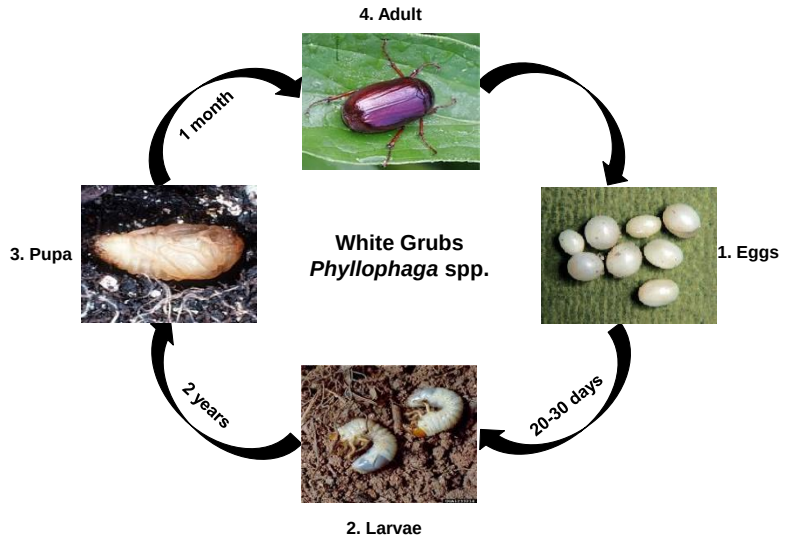
Egg: Eggs are usually 1.5 to 3 mm in diameter, oval in shape and found encased in soil aggregates. The egg is dull, small, spherical, pearly white that darkens just before hatching. The 20-24 mm long pupae may be creamy white, pale yellow or dark brown.

Larva: Older scarab larvae develop within the soil among the roots of their pineapple. They feed upon organic matter within the soil as well. Although white grubs are not immobile, they do not disperse far from where the eggs were laid. White grubs are easily identified by their white or ivory-coloured, 'C'-shaped bodies, which are soft and plump. The posterior quarter to third of the larval abdomen is commonly a dark blue-grey colour, due to the contents of the digestive system. Fully grown grubs of larger species are 2.5 cm or more in length.

Adult: The adults are fairly heavy-bodied insects; most of them with long, spindly legs. They range in colour from light, reddish-brown to shiny black and in size from 12-25 mm in length.

The usual duration of one complete generation (adult to adult) is 2 to 4 years depending upon latitude. Generations, however, are staggered so that grubs and beetles are present every year. Grubs are usually most numerous and damaging the second season following a large beetle flight. With the exception of the common May or June beetle, which has a three-year life cycle, the life history of the beetles mentioned above is completed in 12 months.

Life cycle:



1,3. http://advanceagripractice.in/white-grub/
2. http://forestpests.org/vd/2191.html
4. http://keys.lucidcentral.org/keys/v3/eafrinet/maize_pests/key/maize_pests/Media/Html/White_Grubs.htm

Damage symptoms:

- White grub infestations can destroy roots, causing the affected area to become spongy, which allows the sod to be rolled back like a piece of carpet.
- Evidence of grub damage, including patches of dead or dying turf, are visible during spring (April and May) and late summer and fall (September and October).

8) Fig beetle:

Biology:

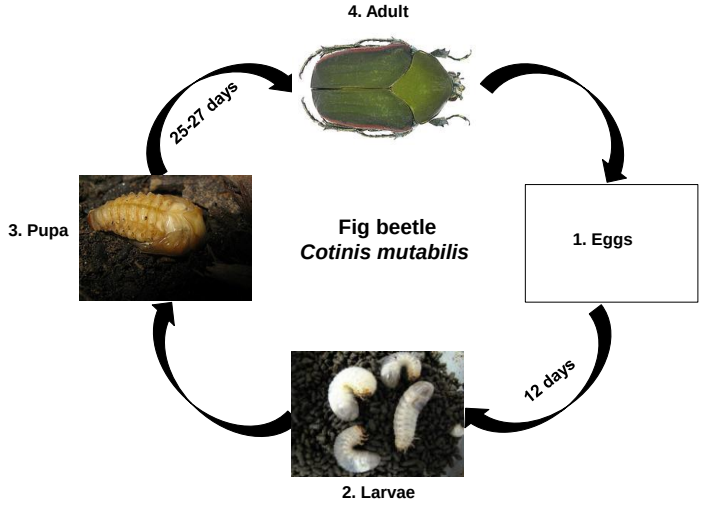
Egg: Females lay eggs (app. 60) in August and the eggs develop into larvae after 12 days and are especially attracted to compost and manure piles. Their eggs are whitish in appearance and be easily found over the soil.

Larva: They have head and legs. They live on soil surface and have a length of 2 inches. Their life includes three instars of which first and second get completed by autumn and the final in the spring season of second year. At rest they curl into C shape. When the larvae get matured they become 2 inches long and become cream coloured. The body of larvae is stiff with brown hairs at the back of the thorax. These hairs are used for locomotion. They form hollow cells in the soil and pupate there.

Pupa: After a few days it reaches a size of 12-50 mm. They develop by June- July. Its duration extends from 25-27 days. The pupae are of size 15 X 25 mm. They are whitish at initial stages and further change to cream coloured as that of larvae stage. At the maturing stages they slightly shift the colour to green.

Adult: They develop by June- November. They lay their eggs in soil. They are white coloured and large sized approximately 12-50 mm in size. They feed on organic matter in soil surfaces. Adults are velvet green in colour. They occupy brownish bands around the edge of the wings and a bright metallic green at the ventral side. Adult females are 17 X 25 mm and adult males are 13 X 22 mm size. At the head portion they are equipped with horn like projections for penetrating into the fruit skin. Adults are tremendous fliers.

Life cycle:



2. http://utahpests.usu.edu/uppdl/htm/arthropods-from-database/beetles/
3,4. http://flickrhivemind.net/Tags/beetle,mutabilis/Interesting

Damage symptoms:

- The plant part affected mainly includes flower parts like pollen, nectar and petals, fruit and larvae damage roots.

9) Pineapple weevil:

Biology:

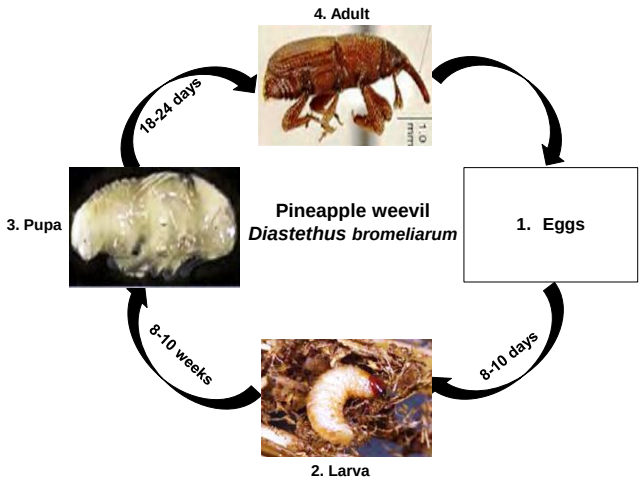
Egg: The eggs are oviposited singly in shallow excavations made usually in the fruit stalk at the junction of the stalk and fruit of the pineapple. More rarely, females lay eggs at the base of the crown and in the basal shoots. The eggs are oval, dull, white and semitransparent.

Larva: The larvae hatch in eight to ten days and tunnel upward in the rootstock or fruit stalk or in the fruit itself. The larval stage lasts for eight to ten weeks. The larvae are white except its head which is brown coloured. It grows to a size of 2.5 cm. The larvae of the pest are infective. It is motile and move up and down destructing the inner tissue of the flower stalk. This affects the normal growth of the fruit causing lack of crown.

Pupa: The pupa is formed at the extremity of the tunnel lasting 18 – 24 days.

Adult: The adults are poor fliers and require a great deal of protection from the direct rays of the sun. It prefers a very humid environment as it shows a preference for the recesses of dense vegetation. They are approximately 16.5mm – 22mm long. The female weevils lay eggs inside a hole within the plant part like base of the crown or base of the shoots. Adults appear 10.6 – 18.2 mm long. They are black or brown coloured with no scales over the body. They feed on leaves causing necrotic edges. Sometimes the fruits they attack rot.
The life cycle completed within 3 – 4 months

Life cycle:



2,3,4. http://prsvkm.tripod.com/Docs/PestsofPineappleandthierManagement.pdf

Damage symptoms:

- The whole life span of the weevil occurs in the same plant.
- The female lays single egg in the slit created by them in the plant leaves. The larvae move to the stem causing tunnels in the plant.
- The larvae pupate in the central stem. There they make cocoon around the body for its growth. If the plant tissue remains enough the adult develops on the same host plant.
- The infestation causes the exudation of a gelatinous material which is protective for the weevil slits. The damage to the host plant includes adult feeding marks on the leaves, leaves browning, decomposition of base of central leaves.

10) Pineapple red mite:

Biology:

Egg: Orange in colour

Larva: The larvae are pale and almost translucent. They often have three pairs of legs in the larval stage and four pairs of legs in the nymph and adult stages.

Adult: Adults, nymph and eggs of this species are bright orange in colour when alive. The adult mite is approximately 0.3–0.4 mm long and 0.1 mm wide. When present on the plant, the mite is always found on the white basal portion of the leaves, where it feeds, particularly on the crown.

Damage symptoms:

- These cause damage to leaves and fruits. Severe infestations produce large, dark brown lesions that almost cover the basal white tissue which can lead to necrosis and death of the leaves.
- In pineapple-production areas, it may frequently cause severe damage to recently established plants in the field.
- Plants that are infested in the early stages remain small and fruit production is either curtailed or non-existent. Heavily infested plants may die before producing fruit.
- It feeds the epidermal tissue to dry and crack which allows fungus and bacteria to enter the plants and cause the tissue rot and scarring and tissue malformation.

Natural enemies of pineapple red mite:

Predators: Syrphid/hover fly, Predatory gall midge (*Feltiella minuta*)

Natural Enemies of Pineapple Insect Pests

Parasitoids

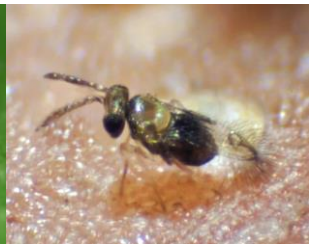
Nymphal and adult parasitoids

1. *Anagyrus ananatis*

2. *Anagyrus kamali*

3. *Aphytis chrysomphali*

4. *Encarsia citrinus*



5. *Encarsia perniciosi*

1. http://www2.ctahr.hawaii.edu/t-star/Anagyrus.jpg
2. http://www.insectimages.org/images/768x512/5195078.jpg
3. http://gipcitricos.ivia.es/ahytis-chrysomphali.html
4. http://www.entocare.nl/english/products_armoured_scales.htm
5. http://www.forestryimages.org/images/768x512/5449520.jpg

Predators

1. Red ant

2. *Cryptolaemus montrouzieri*

3. *Rodolia fumida*

4. *Scymnus coccivora*

5. Mirid bug

6. Dragonfly

7. Damselfly

8. Spider

9. Robber fly

10. Praying mantis

11. Lacewings

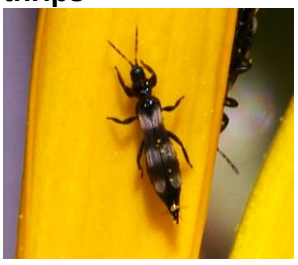
12. *Cheilomenes sexmaculata*

13. *Rhyzobius lophanthae*

14. *Chilocoris infernalis*

15. *Pharoscymnus flexibilis*

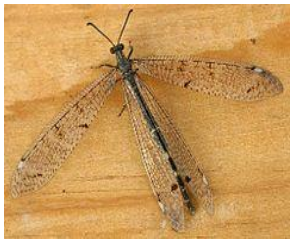
16. Predatory thrips



17. Predatory mite

18. *Orius* sp

19. Antlion



20. Big eyed bugs

21. Rove beetle

22. Hover fly

23. Predatory gall midge (*Feltiella minuta*)

1. http://www.bugsandmitesoff.com/images/Fire_Ant_1.jpg
2. http://www.planetnatural.com/wp-content/uploads/2014/02/mealybug-destroyer.jpg
3. http://www.nbaii.res.in/Featured_insects/images/rodolia-fumida2.jpg
4. http://www.nbaii.res.in/Featured_insects/images/scymnus-coccivora3.jpg
5. http://nathistoc.bio.uci.edu/hemipt/Dicyphus.htm
6. http://www.google.co.in/imgres
7. http://ugly-animals.blogspot.in/2011/07/damselfly.html
9. http://www.warpedphotosblog.com/robber-fly-and-prey
10. http://spirit-animals.com/praying-mantis/
12. http://www.macro-world.cz/image.php?id_foto=514&gal=29
13. http://www.guaminsects.net/uogces/kbwiki/index.php?title=File:Rhyzobius_lophanthae_adult.jpg
14. http://keys.lucidcentral.org/keys/phoenix/ChilocorusSpeciesOfIndia/Chilocorus%20key/html/chilocorus_infernalis.htm
15. http://bugguide.net/node/view/784367
16. http://bugguide.net/images/raw
17. http://www.dongbufarmceres.com/main/mboard.asp?strBoardID=c_product01_en
18. http://en.wikipedia.org/wiki/Orius_insidiosus
19. http://en.wikipedia.org/wiki/Antlion
20. http://bugguide.net/images/raw
21. http://www.ozanimals.com/image/albums/australia/Insect/IMGP7571-600.jpg
23. http://entnemdept.ufl.edu/creatures/beneficial/f_acarisuga.htm

IX. DESCRIPTION OF DISEASES

Fungi associated diseases:

1) *Phytophthora* heart (top) rot:

Damage symptoms:

- Plants of all ages are attacked, but three to four month old crown plantings are most susceptible.
- Fruiting plants or suckers on ratoon plants may be affected.
- The colour of the heart leaves changes to yellow or light coppery brown. Later, the heart leaves wilt (causing the leaf edges to roll under), turn brown and eventually die.
- Once symptoms become visible, young leaves are easily pulled from the plant, and the basal white leaf tissue at the base of the leaves becomes water-soaked and rotten with a foul smell due to the invasion of secondary organisms. The growing point of the stem becomes yellowish-brown with a dark line between healthy and diseased areas.

1. 

2. 

1. http://www.camtacgroup.com/?page_id=46
2. https://www.flickr.com/photos/scotnelson/8250775784/

Survival and spread:

- Chlamydospores of the two species are the primary inoculum and they can survive in the soil or in infected plant debris for several years.
- They germinate directly to produce hyphae that are able to infect roots and young leaf and stem tissue, or indirectly to produce sporangia.
- Phytophthora pathogens are soil inhabitants and require water for spore production and infection. As free water is required for producing sporangia and releasing motile zoospores, infection and disease development is exacerbated in soils with restricted drainage.

2) *Phytophthora* root rot:

Damage symptoms:

- The symptoms above ground are similar to those caused by nematodes, mealy bug wilt and low levels of soil oxygen and are not diagnostic. Leaves change in colour from a healthy green through various shades of red and yellow.
- Leaf tips and margins eventually become necrotic, the root system is dead and plants can easily be pulled from the ground.
- Fruits from infected plants colour prematurely become small and unmarketable. If symptoms are recognized early and control measures are taken plants can recover. If roots are killed right back to the stem, they often fail to regenerate.

1. 2.


1 and 2. https://www.flickr.com/photos/scotnelson/sets/72157635231638212/detail/

Survival and spread:

- Losses can be severe in poorly drained fields. Plants on even relatively well-drained soils can be affected during prolonged wet weather.
- Losses from root rot can be serious in high rainfall areas where prolonged rains extend into the winter months.
- The disease can eliminate the ratoon crop.
- Rough leaf varieties and some low acid hybrids are more susceptible than Smooth Cayenne.

3) Base (butt) rot:

Damage symptoms:

- Symptoms are seen only on crowns, slips and suckers before or immediately after planting. A grey to black rot of the soft butt tissue develops, leaving stringy fibers and a cavity at the base of the stem. If affected material is planted, partial decay of the butt severely reduces plant growth.
- When butt decay is severe, plants fail to establish, wilt rapidly and leaf tissue dies. Unlike Phytophthora heart rot, the young leaves remain firmly attached to the top of the stem. Infected plants can easily be broken off at ground level.

http://www.umuhinzi.com/crop-protection/7539/mu-buhinzi-bwinanasi-indwara-yububore-bwirabura-bwibishibu-cyangwa-urubuto-soft-rot-cyangwa-butt-rot-ni-imwe-mu-zigomba-kwitonderwa-cyane/

Survival and spread:

- The fungus is important in the breakdown of pineapple residues after cropping and survives as chlamydospores in soil and decaying pineapple residues.
- The fungus commonly infects plants through fresh wounds occurring where the planting material has been detached from the parent plant and destroys the soft tissue at the base of the stem.
- Material removed during showery weather and stored in heaps is particularly prone to infection. Tops (crowns) used for planting are particularly susceptible.

- Conidia are produced under conditions of high humidity and can be dispersed by wind. Losses of planting material and plantings from diseased material can be severe at times.

4) Fruitlet core rot (green eye):

Damage symptoms:

- This is an internal fruit disease. Smooth Cayenne fruits do not usually show any external symptoms. However, fruit of the rough-leaf (Mauritius) may produce fruitlets that fail to colour – a condition often referred to as 'green eye'.
- Severely affected fruitlets may become brown and sunken as the fruit ripens. Internal symptoms consist of a browning of the centre of the fruitlets starting below the floral cavity and sometimes extending to the core. The browning, which remains quite firm, varies in size from a speck to complete discolouration of one or more fruitlets.

Penicillium funiculosum and/or Fusarium moniliforme

http://postharvest.ucdavis.edu/PFfruits/PineapplePhotos/?repository=29644&a=83614

Survival and spread:

- *Penicillium funiculosum* infects the developing fruit at some stage between initiation and open flower. Infection is favoured by cool temperatures (16–20oC) during the five weeks after flower initiation, during which time the fungus builds up in leaf hairs damaged by mites. Similar cool temperatures are required for infection from about 10–15 weeks after flower induction.
- Symptoms of fruit let core rot on a fruit cylinder in damaged leaf hairs. *Fusarium guttiforme* enters the fruit through open flowers or injury sites. The risk of disease caused by this fungus is higher when flowers are initiated and fruit mature under warm conditions.

5) Fusariosis:

Damage symptoms:

- It is sporadic and affects all parts of the pineapple plant but is most conspicuous and damaging on fruit.
- Fruits exhibit stem rosetting and curvature of the plant because portions of the stem are girdled or killed.
- Rough leaf pineapple cultivars are more susceptible than smooth-leaf varieties.

http://www.oirsa.org/portal/Fusariosis.aspx

Survival and spread:

- Infections of the inflorescence and fruit occur primarily via injuries caused by insects, particularly the pineapple fruit caterpillar (*Thecla basilides*) and by infected planting materials.

6) Green fruit rot:

Damage symptoms:

- Green fruit in contact with the soil are liable to be infected.
- A water-soaked rot develops internally behind affected fruit lets with no external symptoms, As the disease progresses, a general, water-soaked rot of green fruit with a distinct brown margin develops in green fruit.

Survival and spread:

- The pathogen lives in the soil and requires free water for spore production and fruit infection. Ratoon crop fruit lying close to or touching soil are most affected.
- Spores may be splashed by rain on to fruit near the ground.

7) Interfruitlet corking:

Damage symptoms:

- Fruits affected by inter fruitlet corking often show shiny patches on the shell early in their development, where the trichomes (hairs) have been removed by mite feeding.
- Externally, corky tissue develops on the skin between the fruitlets, but usually only 'patches' of eyes are affected.
- Fine, transverse cracks may also develop on the sepals and bracts.
- In moderate to severe cases, corkiness surrounding fruitlets prevents their development
  and one side of the fruit will be malformed.

8) Leathery pocket:

Damage symptoms:

- Fruits do not usually show any external symptoms. Internally, the formation of corky tissue on the walls of the fruitlets makes them leathery and brown.

Survival and spread:

- See fruitlet core rot. Leathery pocket occurs sporadically. *Penicillium funiculosum*

infects the developing fruit at some stage between initiation and open flower.

- Infection is favoured by cool temperatures (16–20oC) during the five weeks after flower initiation, during which time the fungus builds up in leaf hairs damaged by mites.
- Similar cool temperatures are required for infection from about 10–15 weeks after flower induction.

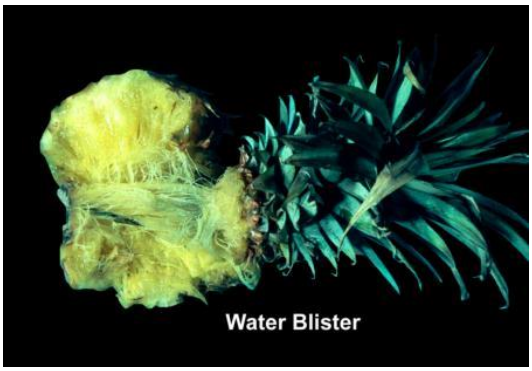
9) Water blister:

Damage symptoms:

- Symptoms include water blister, which is also referred to as black rot or soft rot. This causes a soft, watery rot of the fruit flesh and makes the overlying skin glassy, water-soaked and brittle.
- The skin, flesh and core disintegrate and the fruit leaks through the shell. In advanced cases, this leaves a fruit shell containing only a few black fibres. This shell collapses under the slightest pressure.

1.

2.



1. http://postharvest.ucdavis.edu/PFfruits/PineapplePhotos/?repository=29644&a=83617
2. http://postharvest.ucdavis.edu/PFfruits/PineapplePhotos/?repository=29644&a=83615

Survival and spread:

- Infection occurs through shell bruises and growth cracks but mainly through the broken fruit stalks.
- The disease is most active in warm, wet weather and is most severe from January to April, when the summer crop is harvested. (The correlation between rainfall before harvest and disease after harvest has resulted in the name ‘water blister’).
- When fresh fruits are marketed with the crowns left on, this eliminates a major point of entry for the fungus.

10) White leaf spot:

Damage symptoms:

- The first symptom is a small, brown spot on the leaf, usually where the leaf margin has been rubbed by another leaf during strong winds.
- These spots lengthen rapidly during wet weather. During prolonged wet periods, spots may reach more than 20 cm in length and spread to the leaf tip.
- Fine weather rapidly dries the affected area leaving cream coloured or almost white, papery spots; hence the name ‘white leaf spot’. The margins of the spot often remain brown.

Survival and spread:

- *Chalara paradoxa* is common in pineapple plantations. The fungus will only invade wounds and is most active in warm, wet weather.

11) Fruit rot by yeast and candida species:

Damage symptoms:

- Yeasts ferment sugar solution, producing alcohol and releasing carbon dioxide. The first symptom is a bubbling exudation of gas and juice through the crack or injury where infection occurred.
- The shell then turns brown and leathery and, as the juice escapes, the fruit becomes spongy.
- Internally, the decaying flesh turns bright yellow and develops large gas cavities. Finally, all that remains of the fruit is the shell and spongy tissue.

1. 2.

1. http://postharvest.ucdavis.edu/PFfruits/PineapplePhotos/?repository=29644&a=83619
2. http://postharvest.ucdavis.edu/PFfruits/PineapplePhotos/?repository=29644&a=83618

Survival and spread:

- In spring, rapid changes in fruit growth, resulting from the shift from cold and dry to warm and wet weather, can result in the pineapple skin cracking between fruit lets.
- Fruit affected by even minor frost damage are prone to cracking as they ripen in spring. Yeasts immediately invade the juice weeping from those wounds, and these fruits are severely damaged or destroyed as they ripen. The disease may occur before or after harvest.

12) Nematodes associated diseases:

Damage symptoms:

- Root-knot nematodes produce distinct terminal swellings on the roots, stopping further root development. The root lesion nematode invades the outer root tissues, causing black areas (lesions) of dead or injured plant cells on the root surface.
- These lesions can completely encircle the root. Reniform nematodes reduce the number of lateral and fine feeder roots; the remainder elongate normally so that plants retain good soil anchorage. Root-knot nematodes cause stunting, yellowing and dieback of plants.

http://coursewares.mju.ac.th:81/e-learning47/PP300/0016sugarteam1014/5605nematode/005%20symptom/page_02.htm

Bacteria and phytoplasmas associated diseases:

13) Marbling:

Damage symptoms:

- Infected fruits do not show any external symptoms. Internally, the flesh is red-brown and granular and has a woody consistency.

Survival and spread:

- The disease occurs when flowers are initiated and when fruit mature under warm, wet conditions.
- The bacteria enter through the open flower and natural growth cracks on the fruit surface. Infected fruit are usually low in both acid and sugars.

14) Pink disease:

Damage symptoms:

- Infected fruits do not show any external symptoms, even when fully ripe. Internally, the flesh may be water-soaked or light pink and have an aromatic odour, although these symptoms may not be obvious immediately. When sterilized by heat during canning, infected tissue darkens to colours ranging from pink to dark brown.
- In some fruits, only one or a few fruitlets may be infected. In highly translucent, low-brix fruit, the entire cylinder can be invaded.

Survival and spread:

- The bacteria infect through the open flower during cool weather. Disease incidence increases in dry conditions before flowering, followed by rainfall during flowering.
- The bacteria are thought to be carried by nectar feeding insects and mites to open flowers from infected, decaying fruit near flowering fields.

Virus associated diseases:

15) Mealybug wilt disease:

Damage symptoms:

- The early symptoms are a slight reddening of leaves about halfway up the plant. The leaf colour then changes from red to pink and leaves lose rigidity, roll downwards at the margin and the tip of the leaf dies.
- The root tissue also collapses and the plant appears wilted. Plants can recover to roduce symptomless leaves and fruit that are markedly smaller than fruit from healthy plants.
- Symptoms are most obvious in winter when plant growth and vigour are reduced.
- Disease development and incidence is affected by plant age at the onset of mealy bug infestation, with younger plants displaying symptoms two to three months following feeding, while older plants may take up to 12 months to develop symptoms.

1. 2. 3.




3.

1,2,3. http://www.pestnet.org/SummariesofMessages/Crops/Fruitsnuts/Pineapple/Mealybugwilt,Antigua.aspx

Survival and spread:

- The disease is thought to be caused by viruses transmitted by mealy bugs with the pink mealy bug (*Dysmicoccus brevipes*) being the main vector.
- The disease is probably introduced in planting material that may not show obvious disease symptoms. Once established, the viruses are transmitted when the mealy bugs feed on young leaves. Mealy bugs are sedentary insects that are moved from plant to plant by attendant ants or by wind.
- Ants actively tend mealy bugs. The coastal brown ant (*Pheidole megacephala*) is common and active, but many other species can be involved in raising mealy bugs. Mealy bugs produce honeydew, which is harvested by ants for food. Ants also protect mealy bugs from predators and move them around and between plants. The removal of spiders from fields by ants often allows large populations of mealy bugs to develop, increasing the risk of severe mealy bug wilt outbreaks. The incidence is variable and sometimes high. The amount of wilt in a field is related to the number of mealy bugs present, the length of time they feed and the activity of ants.

16) Yellow spot:

Damage symptoms:

- Infection occurs on young crowns when they are still on the fruit or during the first few months after planting. Small (2–5 mm), round, yellow spots appear on the upper surfaceof the leaves of young plants. These spots fuse and form yellow streaks in the leaf tissue, which soon become brown and die.
- The virus spreads to the leaves in the plant heart, causing the plant to bend sideways. Infection eventually kills the plant so that the virus is not transmitted to subsequent plantings. If the crown is infected while still on the fruit, the fruit dies from the top downwards. Infections can occur through open blossoms causing the development of large, blackened cavities in the side of the fruit.

Survival and spread:

- The viruses are transmitted to pineapple plants by small flying insects (thrips). Infection occurs mostly on plants during early growth, and crowns on developing fruit are occasionally infected.
- As infection is always fatal, vegetative propagation does not spread the virus to subsequent plantings.
- Tospoviruses have a wide range of hosts among weed and crop plants. The disease is rarely seen.

X. DESCRIPTION OF RODENT PESTS

1) Indian porcupine:

- Porcupines are characterized by a large size; fur modified into elongated quills or spines, hairless sole and short limbs; short toes. Short tailed with small white quills. It is characterized by large size with around 10-18 kg. body weight.
- The crested porcupine is distributed throughout India. They inhibit Inhabits rocky habitats around hillocks.
- They cause damage pine apple, potato and maize, tapioca etc.
- Protected under Wildlife (Protection) Act, 1972.

2) Lesser bandicoot:

- Distributed throughout India and infests almost all crops.
- Robust rodent (200 to 300 g body weight) with a rounded head and a broad muzzle. Dorsum covered with grey-brownish rough hairs. Tail is naked, shorter than head and body.
- Breeds throughout the season and litter size 6-8 in normal conditions.
- Nocturnal and fossorial. Burrows are characterized by the presence of scooped soil at the entrance and mostly burrow openings are closed with soil.
- It is a major pest in irrigated rice crop and also causes damage to pineapple.

3) House rat:

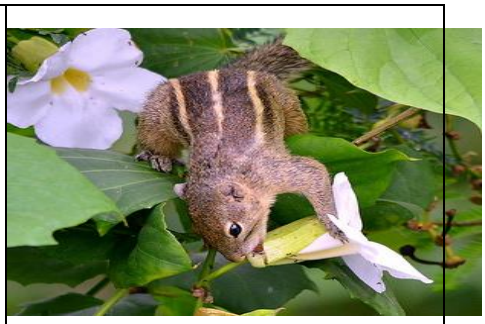
- Distributed throughout India. Medium sized (80-120g) slender rodent. Commonly found in houses and on plantation crops.
- Very good climber with longer tail than head and body. Inhabitation on trees and other places and won't make any burrows in fields.
- Breeds throughout the year producing 5 to 7 litters a year. Serious pest in residential premises and in orchards and horticultural crops.

4) Northern palm squirrel:

- The five-striped palm squirrel, also known as the Northern palm squirrel, inhabits a large part of North India.
- They found in agriculture and horticultural corps and also it will be seen in urban areas. These squirrels possess a bushy tail.
- It has five stripes run from head to tail. On the underside is a belly that is off-white in colour.
- Cause damage to orchards/vegetable crops

5) Southern palm squirrel:

- It has bushy tail with dorsal surface having three distinct white stripes.
- It is a diurnal rodent and lives in the trunks of trees/rocks and orchards.
- It distributed southern parts of India.
- It breeds from March to September with a litter size ranging from 1-5.
- It is a serious pest in Horticultural crops.



Damage symptoms

The rodents cause damage to stem, crown, raw fruit and ripening fruit during the development. The more damage occurs at fruit ripening stage of crop.

Management:

- Disturb and destroy the habitat of the rodents by ploughing the field and trimming of the bunds before transplanting.
- Practice burrow smoking using paddy straw or other natural smoking materials in 'ANGRAU/ NIPHM burrow fumigator' for 2-3 minutes for each burrow.
- Set up the local traps @ 8-10/acre 15 days after transplanting for a period of one month for trapping immigrant rodent population.
- Application of 0.005% bromadiolone in ready to use form (wax blocks) or loose bait in packets near rodent burrows
- Apply 2% Zinc phosphide poison baits when the rodent infestation is very high. Practice pre-baiting incase of ZNP poison baiting. Don't apply ZNP poisons more than one time in a crop season as rodents develop bait shyness to this poison.
- Use of castor based oil repellent against the porcupines.
- Encourage the establishment of natural predator like barn owls by establishing barn owl perches/ wooden boxes in and around the crop fields.

Action plan for rodent management using rodenticide poison baits

Practice poison baiting with anticoagulant, bromadiolone @ 0.005% (96 parts of broken rice + 2 parts of edible oil + 2 parts of 0.25% CB bromadiolone) on community approach.

- DAY – 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc.
- DAY – 2: Count the re-opened burrows and treat the burrows with Bromadiolone chemical bait packets @ 10 g/burrow.
- DAY – 10: Observe the re-opened burrows and repeat baiting

In cases of high level of infestation (>50 live burrows/ha) practice poison baiting with zinc phosphide @ 2.0% on community approach. PRACTICE PRE-BAITING TO AVOID BAIT SHYNESS

- DAY – 1: Close all the burrows in the fields, field bunds, canal bunds and surrounding barren lands etc.

- DAY – 2: Count the re-opened burrows and practice pre-baiting @ 20 g/burrow (98 parts of broken rice + 2 parts of edible oil)
- DAY – 4: Observe the re-opened burrows and treat the burrow with zinc phosphide poison bait (96 parts of broken rice + 2 parts of edible oil + 2 parts of Zinc phosphide) @ 10g/ burrow. Collect the dead rats, if found any outside and bury them.
- If any residual population is found, practice anti-coagulant poison baiting.

XI. SAFETY MEASURES

A) At the time of harvest

Pineapple plants flower 12-15 months after planting and the fruits become ready 15-18 months after planting depending upon the variety, time of planting, type and size of plant material used and prevailing temperature during the fruit development. Under natural conditions, pineapple comes to harvest during May-August. The fruit usually ripens about 5 months after flowering. Irregular flowering results in the harvesting spread over a long period. The fruits are harvested for canning purpose when there is a slight change at the base of developing fruits. The fruits used for table purpose are retained till they develop golden yellow colour.

B) During post-harvest storage

Fruits with crown can be kept without damage for 10-15 days after harvesting. When fruits are transported to long distances or for a period of several days, refrigerated transport is required to slow down ripening process. Pineapples can be stored well for a period of 20 days when refrigerated at 10-13^0 C. The best storage is at 7.2^0 C and 80 or 90% relative humidity.

XII. DO'S AND DON'TS IN IPM

S. No.	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during the months of May and June. The field should be kept exposed to sun light at least for 2-3 weeks	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed's bulbs and/or rhizomes of perennial weeds.
2.	Adopt crop rotation.	Avoid monocropping
3.	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
4	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases.
5	Always treat the suckers/planting material with approved chemicals/biopesticides for the control of seed borne diseases/pests.	Do not use suckers/planting material without seed treatment with biopesticide/ chemicals.
6.	Sow in rows at optimum depths under proper moisture conditions for better	Do not sow suckers/planting material beyond 5-7 cm depth.

	establishment.	
7.	Apply only recommended herbicides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pre-emergent as well as soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or by mixing with soil, sand or urea.
8.	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition.	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
12	Release parasitoids only after noticing adult moth as per field observation	Do not apply chemical pesticides within seven days of release of parasitoids.
13	Apply NPV at recommended dose when a large number of egg masses and early instar larvae are noticed. Apply NPV only in the evening hours after 5 pm.	Do not apply NPV on late instar larva and during day time.
14	In case of pests which are active during night spray recommended biopesticides/ chemicals at the time of their appearance in the evening.	Do not spray pesticides at midday since, most of the insects are not active during this period.
15	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mites, mealybugs etc.	Do not spray pesticides only on the upper surface of leaves.
16	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during preceding 10 days before harvest.
17	Follow the recommended procedure of trap crop technology.	Do not apply long persistent pesticides on trap crop, otherwise it may not attract the pests and natural enemies.

XIII. BASIC PRECAUTIONS IN PESTICIDE USAGE

A. Purchase

1. Purchase only just required quantity e.g. 100, 250, 500, 1000 g/ml for single application in specified area.
2. **Do not** purchase leaking containers, loose, unsealed or torn bags; **Do not** purchase pesticides without proper/approved labels.
3. While purchasing insist for invoice/bill/cash memo

B. Storage

1. Avoid storage of pesticides in house premises.
2. Keep only in original container with intact seal.

3. **Do not** transfer pesticides to other containers; **Do not** expose to sunlight or rain water; **Do not** store weedicides along with other pesticides.
4. Never keep them together with food or feed/fodder.
5. Keep away from reach of children and livestock.

C. Handling

1. Never carry/ transport pesticides along with food materials.
2. Avoid carrying bulk pesticides (dust/granules) on head shoulders or on the back.

D. Precautions for preparing spray solution

1. Use clean water.
2. Always protect your nose, eyes, mouth, ears and hands.
3. Use hand gloves, face mask and cover your head with cap.
4. Use polythene bags as hand gloves, handkerchiefs or piece of clean cloth as mask and a cap or towel to cover the head (Do not use polythene bag contaminated with pesticides).
5. Read the label on the container before preparing spray solution.
6. Prepare the spray solution as per requirement
7. **Do not** mix granules with water; **Do not** eat, drink, smoke or chew while preparing solution
8. Concentrated pesticides must not fall on hands etc. while opening sealed container. Do not smell pesticides.
9. Avoid spilling of pesticides while filling the sprayer tank.
10. The operator should protect his bare feet and hands with polythene bags

E. Equipment

1. Select right kind of equipment.
2. **Do not** use leaky and defective equipment
3. Select right kind of nozzles
4. **Do not** blow/clean clogged nozzle with mouth. Use old tooth brush tied with the sprayer and clean with water.
5. **Do not** use same sprayer for weedicide and insecticide.

F. Precautions for applying pesticides

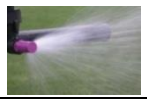
1. Apply only at recommended dose and dilution
2. **Do not** apply on hot sunny day or strong windy condition; **Do not** apply just before the rains and after the rains; **Do not** apply against the windy direction
3. Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer
4. Wash the sprayer and buckets etc. with soap water after spraying
5. Containers buckets etc. used for mixing pesticides should not be used for domestic purpose
6. Avoid entry of animals and workers in the field immediately after spraying
7. Avoid tank mixing of different pesticides

G. Disposal

1. Left over spray solution should not be drained in ponds or water lines etc. throw it in barren isolated area if possible
2. The used/empty containers should be crushed with a stone/stick and buried deep into soil away from water source.
3. Never reuse empty pesticides container for any other purpose.

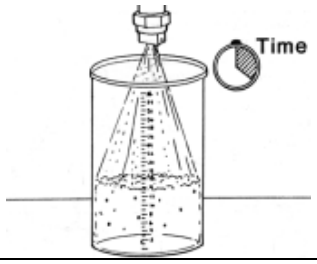
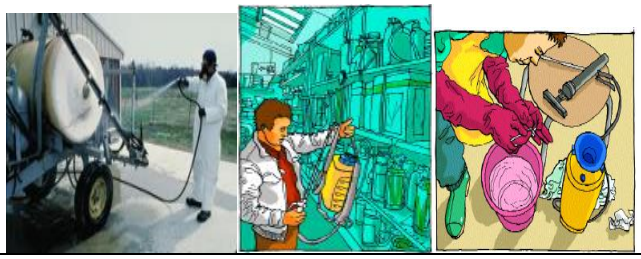
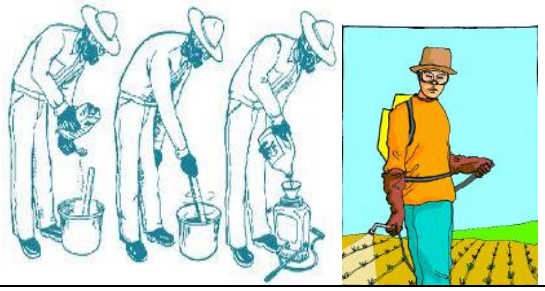
XIV. PESTICIDE APPLICATION TECHNIQUES

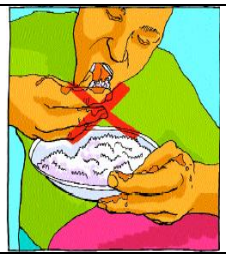
<table>
<tr><th colspan="4">Equipment</th></tr>
<tr><td colspan="4">Category A: Stationary, crawling pest/disease</td></tr>
<tr><td>Vegetative stage
i) for crawling and soil borne pests

ii) for small sucking leaf borne pests</td><td>Insecticides and fungicides</td><td>• Lever operated knapsack sprayer (droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min
or
• Motorized knapsack sprayer or mist blower (droplets of small size)
• Airblast nozzle
• Operating speed: 2/3rd throttle</td><td> 
  </td></tr>
<tr><td>Reproductive stage</td><td>Insecticides and fungicides</td><td>• Lever operated knapsack sprayer (droplets of big size)
• Hollow cone nozzle @ 35 to 40 psi
• Lever operating speed = 15 to 20 strokes/min</td><td>  </td></tr>
<tr><td colspan="4">Category B: Field flying pest/airborne pest</td></tr>
<tr><td>Vegetative stage
Reproductive stage
(Field Pests)</td><td>Insecticides and fungicides</td><td>• Motorized knapsack sprayer or mist blower (droplets of small size)
• Airblast nozzle
• Operating speed: 2/3rd throttle
Or
• Battery operated low volume sprayer (droplets of small size)
Spinning disc nozzle</td><td> 
   </td></tr>
<tr><td>Mosquito/ locust and spatial application (migratory Pests)</td><td>Insecticides and fungicides</td><td>• Fogging machine and ENV (exhaust nozzle vehicle) (droplets of very small size)
• Hot tube nozzle</td><td>   </td></tr>
<tr><td colspan="4">Category C: Weeds</td></tr>
<tr><td>Post-emergence application</td><td>Weedicide</td><td>• Lever operated knapsack sprayer (droplets of big size)
• Flat fan or floodjet nozzle @ 15 to 20 psi
• Lever operating speed = 7 to 10 strokes/min</td><td> 
  </td></tr>
</table>

Pre-emergence application	Weedicide	• Trolley mounted low volume sprayer (droplets of small size) • Battery operated low volume sprayer (droplets of small size)	

XV. OPERATIONAL, CALIBRATION AND MAINTENANCE GUIDELINES IN BRIEF

1.	For application rate and dosage see the label and leaflet of the particular pesticide.	 
2.	It is advisable to check the output of the sprayer (calibration) before commencement of spraying under guidance of trained person.	 
3.	Clean and wash the machines and nozzles and store in dry place after use.	
4.	It is advisable to use protective clothing, face mask and gloves while preparing and applying pesticides. Do not apply pesticides without protective clothing and wash clothes immediately after spray application.	

5.	Do not apply in hot or windy conditions.	 
6.	Operator should maintain normal walking speed while undertaking application.	
7.	Do not smoke, chew or eat while undertaking the spraying operation	 
8.	Operator should take proper bath with soap after completing spraying	  
9.	Do not blow the nozzle with mouth for any blockages. Clean with water and a soft brush.	

XVI. REFERENCE

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